

UNCLASSIFIED

AD NUMBER
AD891210
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution limited to U.S. Gov't. agencies only; Test and Evaluation; Dec 71. Other requests for this document must be referred to Director, Naval Research Lab., Washington, D. C. 20390.
AUTHORITY
NRL ltr, 24 Oct 2001

THIS PAGE IS UNCLASSIFIED

Position-Determining System for Sea-Spider Hydrophone Arrays

W. M. LAWSON, JR.

*Systems Engineering Staff
Acoustics Division*

December 30, 1971

AD No. _____
DDC FILE COPY



DDC
RECEIVED
FEB 4 1972
C

NAVAL RESEARCH LABORATORY
Washington, D.C.

SECTION 101

WHITE SECTION ☐

BUFF SECTION ☒

UNANNOUNCED

JUSTIFICATION

BY

DISTRIBUTION AVAILABILITY CODES

DATE

13

DISCLAIMER NOTICE

**THIS DOCUMENT IS BEST QUALITY
PRACTICABLE. THE COPY FURNISHED
TO DTIC CONTAINED A SIGNIFICANT
NUMBER OF PAGES WHICH DO NOT
REPRODUCE LEGIBLY.**

TABLE OF CONTENTS

	Page
Abstract	ii
Problem Status	ii
Authorization	ii
 INTRODUCTION	 1
BACKGROUND	1
General	1
Pacific Sea-Spider	3
THEORY	4
Position Location	4
Acoustic Paths	9
Other Acoustic Effects	10
Electronic System	13
Transponder	18
HARDWARE AND CIRCUIT DESCRIPTION	19
Starting	21
Control	22
Time Counter	26
Data Storage and Readout	29
RANGE CALCULATIONS	33
RESULTS	35
CONCLUSIONS AND MODIFICATIONS	37
APPENDIX A—Pacific-Sea-Spider Modes and Active Hydrophones	38
APPENDIX B—Position Determining System—Card Layout	39
APPENDIX C—Cable Functions for the System	42
APPENDIX D—Sample Computer Instructions and Readout	46
APPENDIX E—Wiring Chart for Fig. F3	52
APPENDIX F—Complete System Schematics	53

ABSTRACT

An electronic system has been developed which is capable of measuring the elapsed travel time for three acoustic sources to any one of 12, 24, or 36 hydrophones. Though it was developed and configured for the Pacific Sea-Spider array, it is applicable, with modifications, for determining the position of 12 hydrophones relative to three sources in known positions.

Pacific Sea-Spider was a trilegged, moored, subsurface array of 30 hydrophones. It had three acoustic sources, one near each anchor point. The position-determining system developed for this array includes control logic to select any of five sets of 12 hydrophones and a single source, a crystal-controlled clock to measure the travel time, 12 level and phase detectors to determine reception of the acoustic signal and to command time transfer, a storage register with jam transfer of the time data, and output logic to control a paper-tape punch for data output.

The acoustic signal is gated synchronously, and axis-crossing detection is used. The result is a resolution of a 0.1 ms, provided a graphic recorder is used to note the number of the cycle at which detection occurred.

The results on paper tape can be either printed out on a typewriter or used as data input to a digital computer, where with proper programming the coordinates of a particular hydrophone with respect to the known position of the three sources can be calculated.

The system can complete a set of elapsed-time measurements for 12 hydrophones once every 10 seconds. In the Sea-Spider configuration with three legs and 30 hydrophones, the minimum time for a complete set of elapsed-time measurements is 30 seconds.

PROBLEM STATUS

This is a final report on the problem.

AUTHORIZATION

NRL Problem K03-42
Project R2408

Manuscript submitted June 30, 1971.

POSITION-DETERMINING SYSTEM FOR SEA-SPIDER HYDROPHONE ARRAYS

INTRODUCTION

Measurement of acoustic parameters in the deep ocean, especially over long periods of time, has suffered from the lack of stable platforms, both for long- and short-term measurements. One of the proposals for providing stable ocean platforms is the sea-spider hydrophone-array concept.

This concept is a three-legged, wire-rope system moored to the ocean bottom, with all three legs supported at one point below the ocean surface by a float. Hydrophones are distributed along the legs, and the acoustic signals and engineering data from the array are transmitted to a ship or shore station by a radio or wire data link.

Movement of the legs of such a system can be kept quite small by proper design. However, both to verify the design and to monitor the movements in an operational system, it is necessary to provide some means of locating specific hydrophones with reference to other hydrophones or to the sea bottom or surface. This report describes such a position-determining system called POSDETS. Though it is designed for the Pacific Sea-Spider installation, which was to have been implanted in 1969, much of the system and its theory applies to any sea-spider-type installation and to other types of moored arrays as well. No operational experience has been obtained with the system because of the failure of the Pacific-Sea-Spider installation; therefore, operation has been with test signals.

BACKGROUND

General

To locate any point which is free to move in any direction in free space (in this case the ocean volume), a minimum of three distances from three fixed noncolinear, known points in space is required. There are several other schemes which can be used, but all require that either more than three distances or some combination of distances and angles be measured and are thus more complex.

Figure 1 depicts the sea-spider-array concept as designed for the Pacific Sea-Spider. It shows the three fixed anchor points on the ocean bottom and the three wire legs converging from these anchors to an apex where the legs are supported by a subsurface float. If the location procedure of the previous paragraph is to be used, three fixed points on or near the array must be provided and located. The obvious points to use in this array are the leg-anchor points, since all other points on the array are free to move to some degree and since the anchor points are accessible to the data-transmission system.

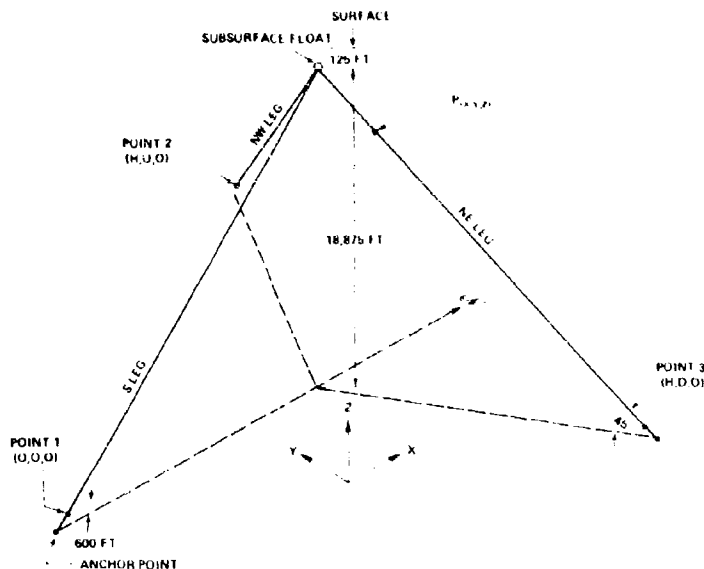


Fig. 1—Array dimensions

The selected fixed points have to be located if they are to be used as references for position measurement. This is done in the ocean by measuring the elapsed time between the transmission of an acoustic pulse from one reference point and its reception at another reference point. Such acoustic transmissions usually follow curved paths of some form. The curved path of a horizontal transmission near the ocean bottom is concave up when viewed from the side and requires that the source and hydrophone for such a path be mounted above the actual bottom if the sound energy is to clear the bottom.

In the Pacific Sea-Spider design, this necessary bottom clearance requires that the source and hydrophone used as reference points be located 600 feet above the ocean bottom. The resulting reference configuration is an acoustic source with a nearby hydrophone, mounted on each leg, approximately 850 feet up the wire from the anchor. The resulting reference points are no longer fixed with respect to the ocean bottom; however, the expected motions are small, less than 10 feet, and should all occur in about the same direction. The latter statement means that the positions with respect to each other should remain relatively fixed, and it is not necessary to calculate the reference coordinates more than a few times.

The acoustic sources are located with respect to each other by using the adjacent hydrophones, measuring the acoustic travel time from one source to the hydrophone on an opposite leg, and performing the necessary calculations for range. The coordinate set of three reference points can then be calculated.

The travel times of one-way acoustic transmissions, from each of the three reference sources to a hydrophone at the desired measuring point P, are then measured. These times are then converted to ranges using the existing velocity profile, and the ranges are used to determine the coordinates of the point P with respect to the sources. Differential movement

from previous positions can be calculated if desired. The accuracy of installation of the anchors is assumed to be good enough that location of the anchor sources with respect to the ocean bottom is not required.

Pacific-Sea-Spider

The Pacific Sea-Spider was to have been installed in the summer of 1969, north of Hawaii, in about 19,000 feet of water. Its configuration was to be that of Fig. 1, with each leg making an angle of 45° with the bottom. All three legs were to each have ten hydrophones on them and were to be spaced according to Fig. 2, where an assumed depth of 19,000 feet is used. The motion study of this array was to use the northwest leg, primarily because of the more even spacing of the hydrophones. However, the other legs were to be measured also to determine such things as the overall shape and location of arrays.

Each of the hydrophones was to be connected to a voltage-controlled oscillator, and the oscillators in turn were to be multiplexed to a radio transmitter in a surface buoy tethered to the subsurface float. Demodulation equipment aboard a research ship was to have allowed as many as 12 hydrophones to be monitored at one time, along with appropriate engineering-type data.

An acoustic source was to be mounted about 850 feet from the anchor along each wire leg. This results in the source being about 600 feet above the ocean bottom, as required for

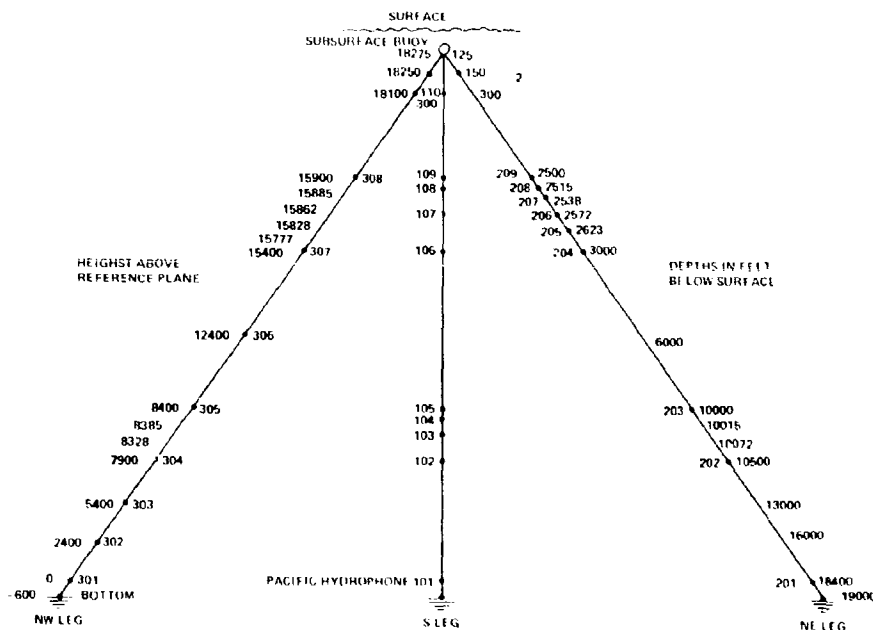


Fig. 2 Hydrophone locations

acoustic-travel path clearance. A hydrophone was to be mounted near each of these three sources to allow their location with respect to each other to be determined. The electrical waveform necessary to produce the acoustic pulse from the three sources was to be radio-telemetered from the monitoring ship. This would result in an insignificant time delay of the order of microseconds between the initiation of the waveform of the ship and the initiation of the acoustic waveform in the water.

Thus the Pacific Sea-Spider would have provided three acoustic sources in relatively fixed locations, the hydrophones necessary to locate these sources easily, and a number of hydrophones on each leg to measure the movement at those points.

This report describes the details of the measuring system (acoustic receivers and travel-time meter), the control system, and the limiting parameters and expected ranges of these systems when used with the Pacific Sea-Spider.

THEORY

Position Location

The Pacific Sea-Spider was to have been implanted with one of the legs on a north-south axis with the anchor to the south (Fig. 1). This south anchor area was chosen to be the origin of the coordinate system so that the +X axis would lie from south to north. The acoustic source/hydrophone complex about 600 feet off the bottom is the actual reference point and is given the coordinates 0, 0, 0.

Figure 3 shows a view of the reference plane (all sources were to be assumed to have been installed at the same depth by adjustment of the leg length) looking down from the surface. A perpendicular is constructed from reference point 1 to a line drawn between points 2 and 3. The length of this line is called H and gives an X coordinate, at points 2 and 3, of H. The length between the intersection point, of the line between points 2 and 3 and the perpendicular, and point 2 is called U; for point 3 it is called D. If the base triangle thus attained is equilateral, as it was to have been in Pacific Sea-Spider, then U will be equal to D, as shown by the dimensions in Fig. 3.

In practice points 1, 2, and 3 are source/hydrophone systems. One then measures the acoustic travel-time between source 1 and hydrophones 2 and 3 and between source 2 and hydrophone 3. These are converted to range R, as described later.

If the three ranges obtained in this measurement are equal, then U must equal D, and from the equilateral triangle

$$U = -D = 0.5 R \quad (1)$$

and

$$H = 0.86603 R. \quad (2)$$

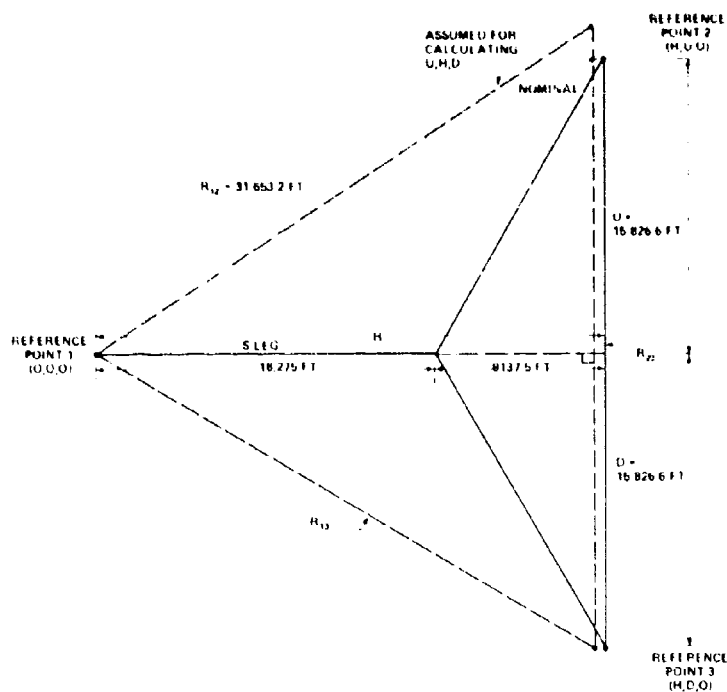


Fig. 3—Nominal geometry, dimensioned for a 19,000-ft depth

If the ranges R_{12} and R_{13} are equal, an isosceles triangle exists, and the following relations apply:

$$U = -D = 0.5 R_{23}; \quad (3)$$

$$H = +\sqrt{(R_{12})^2 - 0.25 (R_{23})^2}. \quad (4)$$

If the three ranges R_{12} , R_{13} , and R_{23} are different or if R_{12} does not equal R_{13} , then the location of the three sources with respect to each other and the constructed X axis may be found from the general equation of trigonometry for determining the height of a triangle and from the other three equations relating the sides of a right triangle. These equations are:

$$H = \frac{2\sqrt{S(S-R_{12})(S-R_{23})(S-R_{13})}}{R_{23}}, \quad (5a)$$

where

$$S = \frac{R_{12} + R_{23} + R_{13}}{2}, \quad (5b)$$

$$R_{12}^2 = H^2 + U^2, \quad (6a)$$

$$R_{13}^2 = H^2 + D^2, \quad (6b)$$

and

$$R_{23} = U + D. \quad (6c)$$

Solving for D in Eq. 6c, substituting in Eq. 6b, and subtracting Eq. 6b from Eq. 6a yields

$$U = \frac{R_{12}^2 + R_{23}^2 - R_{13}^2}{2R_{23}}. \quad (7)$$

Similarly, solving for U, substituting in Eq. 6a, and subtracting Eq. 6b from Eq. 6a yields

$$D = - \left(\frac{R_{23}^2 + R_{13}^2 - R_{12}^2}{2R_{23}} \right), \quad (8)$$

where D will be a positive number but is prefixed by a negative when used as a coordinate of point 3 in other calculations.

The above procedure determines the relative position of the three base-triangle reference points with respect to each other. If the values of U and D, as determined from Eqs. 7 and 8, differ by less than 1000 feet, then the array will have been installed such that the X axis, as measured, is not off from the predicted direction by more than 1 degree. It can then be assumed that the installation accuracy is good enough that the X axis, as measured, can be assumed to be oriented north-south, as intended. The relative coordinate system then can be used as an absolute coordinate system as well, and all array position measurements can be considered to be referenced to the ocean bottom. Such installation accuracy is assumed to be obtainable, and no procedures for measuring anchor-source position with respect to the ocean bottom are given herein.

The general equation for the distance from a point o to a point p in three dimensional space is

$$R_{op}^2 = (X_p - X_o)^2 + (Y_p - Y_o)^2 + (Z_p - Z_o)^2. \quad (9)$$

Since there are three unknowns, the coordinates of the point p in Fig. 1, three equations will be required. These will be for the ranges from the three sources at the base of the array. Using the coordinates of the three reference points shown in Fig. 1, these three equations are

$$R_{1p}^2 = (X_p - O)^2 + (Y_p - O)^2 + (Z_p - O)^2; \quad (10a)$$

$$R_{2p}^2 = (X_p - H)^2 + (Y_p - U)^2 + (Z_p - O)^2; \quad (10b)$$

$$R_{3p}^2 = (X_p - H)^2 + (Y_p - D)^2 + (Z_p - O)^2. \quad (10c)$$

Performing the indicated operations yields

$$R_{1p}^2 = X_p^2 + Y_p^2 + Z_p^2; \quad (11a)$$

$$R_{2p}^2 = X_p^2 - 2HX_p + H^2 + Y_p^2 - 2UY_p + U^2 + Z_p^2; \quad (11b)$$

$$R_{3p}^2 = X_p^2 - 2HX_p + H^2 + Y_p^2 - 2DY_p + D^2 + Z_p^2. \quad (11c)$$

If Eq. 11a is subtracted from the other two equations, the resulting equations are

$$R_{2p}^2 - R_{1p}^2 = H^2 - 2HX_p + U^2 - 2UY_p; \quad (12a)$$

$$R_{3p}^2 - R_{1p}^2 = H^2 - 2HX_p + D^2 - 2DY_p. \quad (12b)$$

If Eq. 12b is subtracted from Eq. 12a, the result is

$$R_{2p}^2 - R_{3p}^2 = U^2 - D^2 - 2(U - D)Y_p \quad (13)$$

or

$$-2(U - D)Y_p = R_{2p}^2 - R_{3p}^2 - U^2 + D^2 \quad (14)$$

and

$$Y_p = \frac{R_{3p}^2 - R_{2p}^2 + U^2 - D^2}{2(U - D)}. \quad (15)$$

If Eq. 12a is multiplied by D and Eq. 12b by U, then

$$D(R_{2p}^2 - R_{1p}^2) = DH^2 - 2DHX_p + DU^2 - 2DUY_p; \quad (16a)$$

$$U(R_{3p}^2 - R_{1p}^2) = UH^2 - 2UHX_p + UD^2 - 2DUY_p. \quad (16b)$$

Subtracting Eq. 16b from Eq. 16a yields.

$$(D - U)H^2 - 2H(D - U)X_p + UD(U - D) = DR_{2p}^2 - UR_{3p}^2 - (D - U)R_{1p}^2. \quad (17)$$

Rearranging gives

$$-2H(D - U)X_p = -(D - U)R_{1p}^2 + DR_{2p}^2 - UR_{3p}^2 - (D - U)H^2 - UD(U - D). \quad (18)$$

Changing signs in the $(D - U)$ terms and dividing gives

$$X_p = \frac{(U - D)R_{1p}^2 + DR_{2p}^2 - UR_{3p}^2 + (U - D)H^2 - (U - D)UD}{2H(U - D)} \quad (19)$$

The Z coordinate is found by using Eq. 11a and the results of Eqs. 15 and 19 and is

$$Z_p = +\sqrt{R_{1p}^2 - X_p^2 - Y_p^2} \quad (20)$$

The positive square root is chosen, since all the points P of the Pacific Sea-Spider were to have been above the reference plane.

The legs of the Pacific Sea-Spider are intended to be adjusted in length during installation to compensate for variations in the actual ocean-bottom topography from an ideal flat surface. Nonetheless, it is useful to assign a nominal depth and to compute the various path and lengths of the array. Such computations have been made to predict the approximate mute- and arrival-time values for each path and configuration for use in designing the electronics system.

These computations can be done using Fig. 2, which shows the nominal height of the various measuring points above the reference plane, and Fig. 4, which shows the development of the dimensions of the cable-plane, that slanted plane which includes two of the three legs.

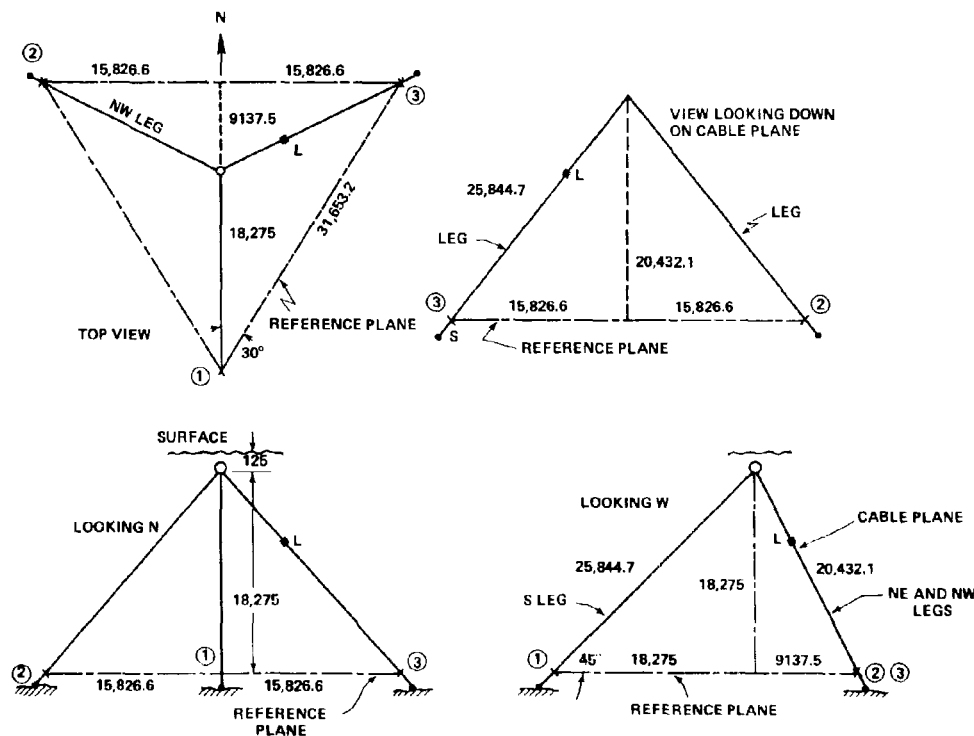


Fig. 4—Pacific Sea-Spider dimensions

Three ranges need to be measured to any hydrophone point L (Fig. 4) to determine the coordinates of that point. However, these three ranges in the nominal array are on three identical cable planes. Therefore, there are only two classes of ranges to be measured, an upleg class and a crossleg class. These are represented in Fig. 4 by the range from source point 3 up a leg to point L and by the range from either source point 1 or 2 across the cable plane to the point L.

Figure 2 gives all elevations from the base triangle for all 16 possible hydrophone positions. The two classes of ranges are found by use of trigonometric equations. For the nominal array, with legs at 45° to the bottom, the upleg range is given by

$$(R_{SL})_u = \sqrt{2D_L}, \quad (21)$$

where D_L is the height of the desired hydrophone above the reference plane. The crossing range is found by subtracting the height D_L from the reference base of 31,553.2 ft and using that value and D_L as the legs of a right triangle. The equation after doing this works out to be

$$(R_{SL})_c = \sqrt{2D_L^2 - 63306.4 D_L + 1,001,925,070.2}. \quad (22)$$

Performing these computations for the hydrophone heights given in Fig. 2 yields the values given in Table 1, assuming a straight-line path geometry. As an example of the use of this table, consider hydrophone number 306 at the 6000-foot depth on the northwest leg. The ranges associated with this hydrophone are R_{16} , R_{26} , and R_{36} . Referring to Fig. 1 for the assigned reference points, R_{26} can be seen to be an upleg range. Thus the nominal ranges to be used in the determination of the coordinates of hydrophone 306 are respectively 25,092.2 feet, 17,536.2 feet, and 25,092.2 feet.

Acoustic Paths

The primary method of measuring a distance underwater is to measure the elapsed time it takes an acoustic pulse to travel from a source to a reception point. The path that such an acoustic pulse follows in sea water is rarely a straight line but rather is a curved path determined by the sound velocity as a function of depth. For this reason and to provide bottom clearance, the sources of this design are placed 600 feet above the ocean bottom.

The distance measurements made in an operating sea-spider array will not, in general, be measurements of the desired straight-line distance but will be measurements of a curved path. To determine the straight-line range, it is necessary to use an average velocity profile to determine the paths that acoustic energy will take for the nominal configuration of the Pacific Sea-Spider and from this to determine the average velocity involved in any path and what, if any, correction will be required to go from the curvilinear to the straight-line distance. Accordingly a typical summer velocity profile, defined by the values given in Table 2, from the area where Pacific Sea-Spider was to be implanted has been used along with the nominal array geometry in a ray-trace program to calculate the average ray velocity, travel time, and range. The results for the cross-leg measurements are given in Table 3, and for selected up-leg measurements they are given in Table 4.

Table 1
Predetermined Up- and Cross-Leg Ranges for the
Nominal Pacific Sea-Spider Hydrophone Array

Hydrophone	Hydrophone*	Height Above Reference Plane	Up-Leg Range	Cross-Leg Range
Level Number	In Use	(ft)	(ft)	(ft)
1	101, 201, 301	0	0.0	31,653.2
2	302	2400	3394.1	29,696.2
3	303	5400	7636.8	27,644.0
4	102, 202, 304	7900	11,172.3	26,336.8
5	103	8328	11,777.6	26,154.4
6	104	8385	11,858.2	26,131.1
7	105, 203, 305	8400	11,879.4	26,125.0
8	306	12,400	17,536.2	25,092.2
9	106, 204, 307	15,400	21,778.9	25,138.5
10	205	15,777	22,312.0	25,194.9
11	107, 206	15,828	22,384.2	25,203.3
12	207	15,862	22,432.3	25,209.1
13	108, 208	15,885	22,464.8	25,213.1
14	109, 209, 308	15,900	22,486.0	25,215.7
15	110, 309	18,100	25,597.3	25,784.0
16	210, 310	18,250	25,809.4	25,836.0

*100-series hydrophones are on the S leg;
 200-series hydrophones are on the NE leg;
 300-series hydrophones are on the NW leg.

It can be seen from these tables that the assumption that the measured acoustic ranges were obtained from a straight-line path rather than from a curvilinear path produces an absolute range value that is short for a particular path by a constant error of a maximum value of 8.8 feet. This corresponds to a fixed percentage error in range of -0.032 per cent maximum, which could be calibrated out of the results in the computation process. However, since it is extremely doubtful that the capability of either measuring acoustic velocity or converting the measurements to an average velocity over a ray path will be as good, percentage wise, and since the error, being fixed, will not affect relative-position measurements, the assumption of straight-line path travel rather than curvilinear travel has been accepted for the Pacific Sea-Spider.

Other Acoustic Effects

The measuring of the acoustic-travel time for a water path is affected both by the receiving system and the transmitting system, and for the Pacific Sea-Spider design both systems prove to have limitations. To begin with, the transducer being used as an acoustic

Table 2
Velocity Profile from the Sea-Spider Area (Pacific)
for July 1, 1969

Depth (ft)	Velocity (yd/s)
0.0	1673.8
9.8	1673.8
196.9	1674.8
229.7	1675.0
295.3	1672.8
328.1	1670.9
393.7	1668.0
459.3	1664.3
525.0	1660.1
590.6	1657.4
656.2	1654.7
721.8	1650.7
787.4	1646.5
984.3	1636.6
1312.4	1627.8
2296.7	1621.6
3281.0	1621.6
5905.8	1628.2
6562.0	1631.3
9843.0	1648.6
15,289.5	1680.3
18,869.0	1702.0
19,000.0	1703.5

source by the Pacific Sea-Spider has a maximum specified slew rate or change of frequency from a fixed frequency, per unit time, of 250 Hz/s. The transmitter-system power availability, along with reflection considerations in the acoustic environment, dictate that short acoustic pulses, less than 100 ms duration, should be used. Together these considerations make the use of the phase-shift, FM-slide, or PRN signals of doubtful value in the detection of either energy or arrival phase. Consequently level or energy detection is designed into this system.

If one is to use energy-level detection, then the greater the bandwidth in cycles which can be used in the water medium, the greater the resolution capability. This requires for a fixed Q a high frequency. Because sound in water travels at a rate of about 5 ft/ms, a frequency of 12 kHz should be used when Q is of the order of 4 if 5- to 10-foot resolution is to be obtained from simple level detection. Unfortunately the Pacific Sea-Spider system has an upper frequency limit of 1 kHz.

Detection systems using a 1-kHz signal require not only that the energy level be detected but also that the actual arrival phase be measured. The latter requirement dictates that the acoustic signal being transmitted must be coherent, that is, a single-frequency sine

Table 3
Pacific Sea-Spider Across-Leg, Ray-Trace Calculations and
Error Due to a Straight-Line Travel Path Assumption

Hydrophone Level Number	Average Ray Velocity (yd/s)	Ray Travel Time (ms)	Ray Range (ft)	Straight-Line Range (ft)	Error	
					(ft)	(%)
1	1701.407	6203.1	31,662.0	31,653.2	8.8	-0.028
2	1693.506	5845.3	29,697.2	29,696.2	1.0	-0.003
3	1685.028	5470.3	27,652.8	27,644.0	8.8	-0.032
4	1677.534	5234.8	26,344.7	26,336.8	7.9	-0.030
5	1676.249	5202.5	26,162.1	26,154.4	7.7	-0.029
6	1676.078	5198.5	26,139.3	26,131.1	8.2	-0.031
7	1676.033	5197.4	26,133.0	26,125.0	8.0	-0.031
8	1664.169	5027.1	25,097.8	25,092.2	5.6	-0.021
9	1656.194	5060.4	25,143.0	25,138.5	4.5	-0.018
10	1655.342	5074.2	25,198.6	25,194.9	3.7	-0.015
11	1655.230	5076.3	25,207.3	25,203.2	4.0	-0.016
12	1655.156	5077.7	25,213.2	25,209.1	4.1	-0.016
13	1655.106	5078.7	25,217.4	25,213.1	4.3	-0.017
14	1655.073	5079.3	25,219.8	25,215.7	4.1	-0.016
15	1652.373	5202.0	25,786.9	25,784.0	2.9	-0.011
16	1652.545	5211.9	25,838.7	25,836.0	2.7	-0.010

Table 4
Pacific Sea-Spider Up-Leg, Ray-Trace Calculations and
Error Due to a Straight-Line Travel Path Assumption

Hydrophone Level Number	Average Ray Velocity (yd/s)	Ray Travel Time (ms)	Ray Range (ft)	Straight-Line Range (ft)	Error	
					(ft)	(%)
1	—	0.0	0.0	0.0	0.0	0.000
2	1692.754	668.4	3394.3	3394.1	-0.2	-0.006
3	1683.928	1511.7	7636.8	7636.8	0.0	0.000
7	1675.140	2363.9	11,879.6	11,879.4	-0.2	-0.002
8	1663.641	3513.9	17,537.6	17,536.2	-1.4	-0.008
14	1654.885	4529.7	22,488.4	22,486.0	-2.4	-0.011
15	1652.362	5164.3	25,599.9	25,597.3	-2.6	-0.010

wave always starting at the same phase, preferably on the axis crossing. The detection of this signal then is a process of using level detection (energy) to enable an axis-crossing detector. The axis-crossing detector will measure arrival phase.

For acoustic signals with a one- or two-cycle rise time, the preceding detection process will detect an axis crossing at a constant, fixed cycle, say the second one, and a

fixed correction equal to the total period of the number of cycles before detection occurs may be used to correct the elapsed time.

Unfortunately the transducer design used with Pacific Sea-Spider produces an acoustic signal with a rise time corresponding to about 8 to 10 cycles. In a noisy environment or in the presence of signal-amplitude fluctuations, the detection point of such a waveform can easily vary from one to several cycles. Therefore, for best repeatability of results, the actual cycle at which axis-crossing detection occurs must be determined, and a correction in milliseconds to the measured travel time must be made which is equal, for a 1-kHz waveform, to the number of cycles between the start of the acoustic pulse and the axis-crossing detection. The rise time of the bandpass filter in the receiving system is designed for about 5 cycles to provide adequate filtering with a reasonable rise time for the source used.

Electronic System

The electronic position-measuring system which is described in this report contains three basic sections. These are (a) the master clock, muting, and sequence control; (b) the acoustic-signal detectors; (c) the data storage and readout system. Figure 5a is a simplified block diagram for a single hydrophone channel, and Fig. 5b is a complete block diagram of the system. The general system design is discussed in the following paragraphs.

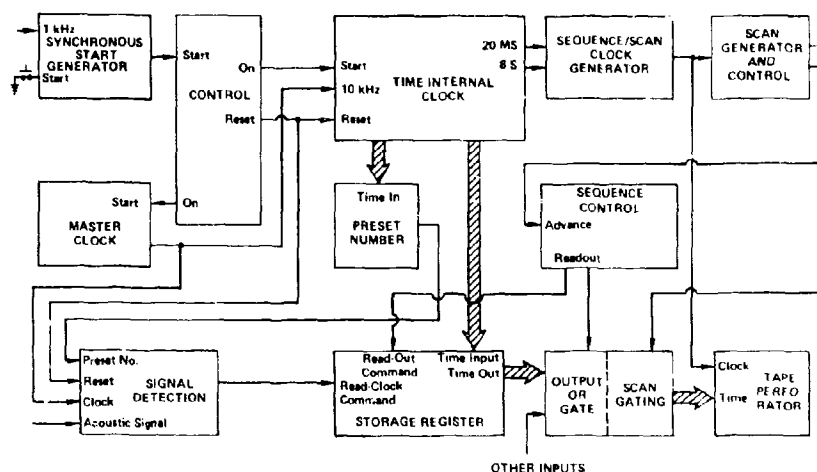


Fig. 5a—Pacific Sea-Spider position-determining system (POSDETS) simplified block diagram for one hydrophone

The acoustic parameters discussed in the previous section dictate that a coherent signal be transmitted. This is done in the controller section by detecting the positive-axis crossings of a continuous 1-kHz signal which is to be transmitted. This detection is used to gate out the manual-start pushbutton command, which in turn develops the necessary level to turn on the acoustic-transmitter signal gate for the required time for the number of cycles being sent.

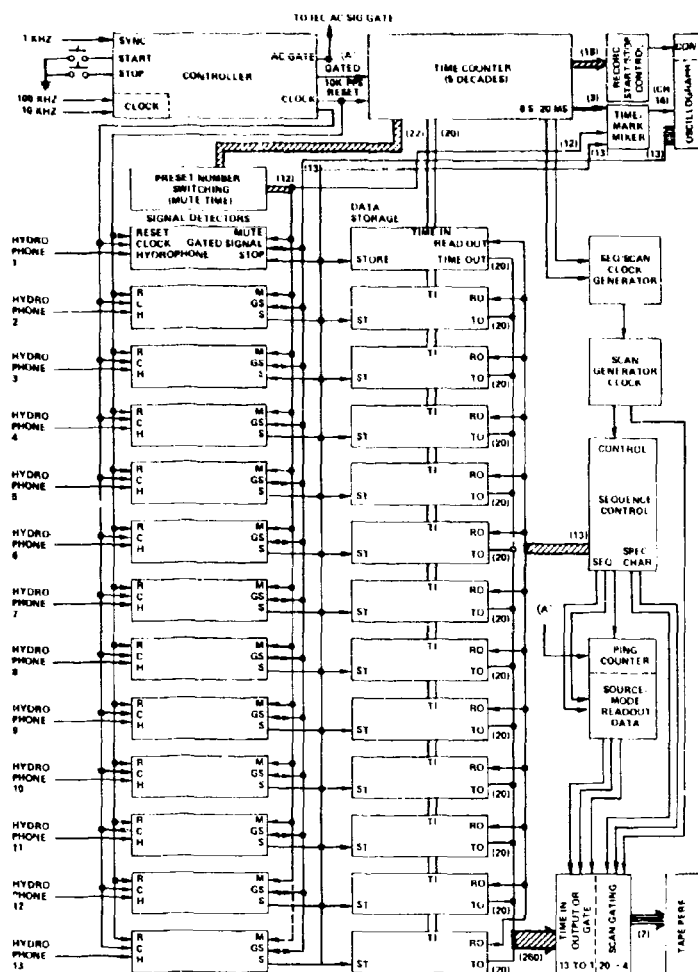


Fig. 5b—Complete POSDETS block diagram

In addition the time counter is started from 0.0 ms. If rise time and signal level are consistent enough that detection can always be assured on a specific cycle, say the third cycle, then the clock could be started from 3.0 ms and no cycle-ambiguity corrections to the travel time would be needed. For the Pacific Sea-Spider design, this provision is not used.

The controller contains two counters to provide for delay between pulses and for sequencing of sources. The initial intent was to have allowed for a fully automatic operation where, with one push of the start button, three successive acoustic signals of 8-ms length, spaced a minimum of 10 s apart in the Pacific Sea-Spider because of the ranges and travel times involved, would be sent from three successive sources. The Pacific Sea-Spider electronics design will not allow this because of the computer-controlled source selection. Therefore, the system is designed for both automatic and semiautomatic operational modes.

In the latter mode one push of the start button starts the sequence, and after the pre-selected delay the counters stop. During this interval the south source of the Pacific Sea-Spider is called for and selected. A push of the button sends the acoustic ping from this source. After the preset delay the clock stops again, awaiting assurance that the second or NW source has been selected and allowing time for the travel times to be measured and read out. After assuring the selection of the NW source, another push of the button sends out the ping from the NW source. After the preset delay the clock stops yet again, during which, or previous to which, the third or NE source is selected. A final push of the button sends out the third ping. After the preset delay the entire system resets and shuts down, awaiting the next cycle.

The frequency and source characteristics of the Pacific Sea-Spider design have determined the choice of level detection of the acoustic signal. The travel times being measured vary from about 0.5 s to 6 s. Thus there is a great possibility of false detection of noise, even if narrow-band filters are used. To reduce this possibility, muted detectors are designed into the system. Time signals from the clock are fed to preset-number switching to provide a signal which removes the mute just prior to the expected time of signal arrival. These same signals are also mixed with the time signals from the clock and recorded on the oscillograph, and thus provide a known time to aid in visual readout of elapsed time from the oscillograph if required as a back up. The stop signal which indicates that a signal was detected is also mixed into the time signals as a further aid in visual readout of the oscillograph recording if necessary.

After all pulses have been received and read out, each signal detector, which can only produce one output, is rearmed and muted, ready for the next ping. Each detector has inputs for the reset, mute, and hydrophone signals. A clock signal is provided to synchronize the readout of the time meter while it is still counting. A resolution of 0.1 ms is chosen to provide approximately 0.5-ft range resolution.

Buffer storage of the reading of a single time counter is used as a money and space economy measure. The signal detectors each provide a 0.05-ms read signal to the buffer-storage input gates and to the time mixer for recording. Each detector also provides an amplified acoustic signal to an oscillograph channel. This signal is gated to a negative level during the cycle after axis-crossing detection for identification purposes.

The detectors are shown in Fig. F2 of Appendix F in the rear of this report. Their operation can be described with the use of the timing diagram of Fig. 6 and the schematic (Fig. F2).

The mute signal* (A) sets a control flip-flop (B) which will now allow hydrophone signals and an axis-crossing detection to pass. The acoustic signal (C) drives two Schmidt triggers. One of these is set to trip on a negative-going voltage which is set to be greater than the average peak-noise voltage and less than the maximum peak-signal voltage. When the

*All capital letters refer to signals shown in Fig. 6.

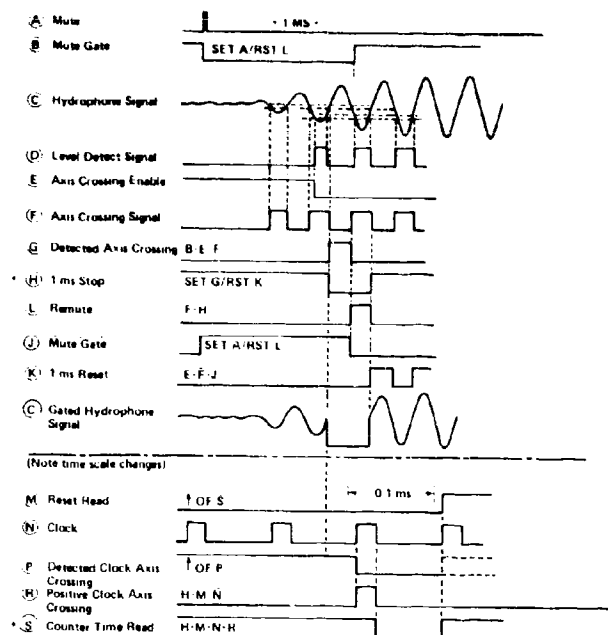


Fig. 6—Hydrophone-detector logic timing diagram

acoustic signal becomes sufficiently large, the change in the Schmidt trigger sets a flip-flop (E), enabling a gate which will pass the output of the other Schmidt trigger (F). This latter trigger is set to switch at zero volts, positive going, to detect the axis-crossing.

The output of the axis-crossing detection gate (G) is used to set a flip-flop (H) for 1 ms. This signal is used to allow the clock (N) to produce a signal time-counter read pulse (S) in synchronization with the clock, to gate the acoustic signal (C'), and to modulate the time channel.

Each read signal from each detector is fed to the input gates of a flip-flop storage register and gates into this register, in parallel, the BCD-coded time count with a resolution of 0.1 ms and a maximum capacity of 9999.9 ms. This portion will be detailed later in this report.

After a period of 8 s all of the data should have been received, and a pulse is transmitted to the output clock-control circuits if in the automatic-readout mode. The data in the first hydrophone storage register are gated out in parallel (20 bits) and scanned out serially, 4 bits at a time, to a paper-tape perforator. Appropriate blanks, decimals, and carriage returns are inserted by the scanner. The sequencer also gates out the ping counter, the mode of operation of the Pacific Sea-Spider, and the source in use.

Manual display of one register at a time is available on panel-mounted Nixie lights. Any Register can be selected, or each can be read out in sequence.

Figure 7 is the complete system block diagram for the Pacific Sea-Spider. This report will not go into much detail about the Pacific Sea-Spider system. Suffice it to say that the internal oscillator of that system has sufficient designed accuracy to be used for the type of detection discussed previously. Two signals were required of the POSDETS; these were a signal gate, starting at a positive-axis crossing and exactly as long as the number of acoustic cycles to be transmitted, and another gate which starts before and lasts longer than the signal gate and is used to turn on the telemetry transmitter.

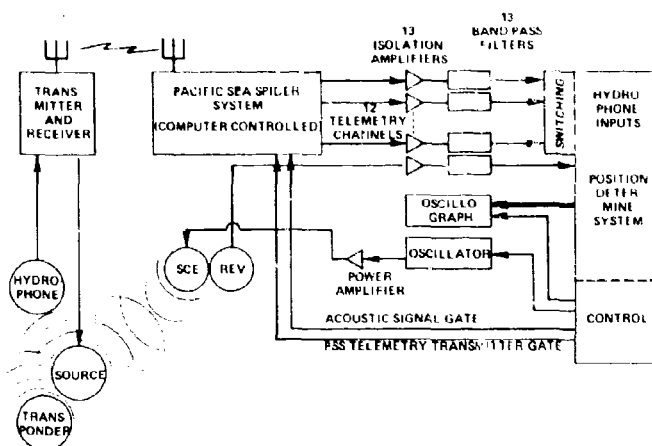


Fig. 7—Pacific Sea-Spider hydrophone-array complete system block diagram

The particular leg source of the Pacific Sea-Spider which is to transmit is selected manually by an input to a computer. Likewise selected is the reception mode, those hydrophones which are to be monitored. These are listed in Appendix B.

The demodulated acoustic-signal telemetry channels, 12 in all, provided as outputs from the Pacific Sea-Spider, are buffer-amplified, filtered, and connected to the POSDETS. Relays controlled by POSDETS connect the incoming telemetry channels to the proper hydrophone detectors according to the mode in which Pacific Sea-Spider is being used.

The hydrophone signals after detection are recorded on the oscillograph along with the time, preset times, and the time-read pulses. The elapsed time is recorded on punched tape in the following format:

Ping Number / Carriage Return (CR) / Source / CR / Travel Times 1 - 5 / CR /
Travel Times 6 - 10 / CR / Travel Times 11 - 13 / CR / Mode / CR.

To be compatible with the computer program to be described later, the digits are in the format (B = blank; N = digit):

```
BBNNN(CR)
BBNN(CR)
BBNNNN.NBBNNNN.NBBNNNN.NBBNNNN.NBBNNNN.N(CR)
BBNNNN.NBBNNNN.NBBNNNN.NBBNNNN.NBBNNNN.N(CR)
BBNNNN.NBBNNNN.NBBNNNN.N(CR)
BBNN(CR).
```

Transponder

The Pacific Sea-Spider array design is an experimental system located in very deep water. Therefore, cost and complexity are such that servicing components of a position-measuring system is impractical. Yet position-measurements of such an experimental system are of great importance. Therefore, transponders have been designed to be used as substitutes for the original acoustic sources should any of them have failed. Provision for using these transponders is designed into the POSDETS; since the same transducers are used in the transponder as are used in the Pacific Sea-Spider, no changes in the detection system are necessary.

Before using a transponder in place of a leg source, the transponder must be located, i.e., U, H, and D of the reference triangle must be determined. To make this fairly easy, to retain as nearly as possible the same nominal configuration, and to make installation easier, the transponders should be placed as near the failed leg source as possible. Then, in essence, for any leg for which a transponder is being used instead of the leg source, the POSDETS time counter is started at a predetermined time before the 0 time. This precount is intended to be approximately equal to the one-way travel time from the surface to the transponder. If the precount is properly selected, the time counter will read approximately 0.0 ms when the transponder transmission starts. In this way the muting circuits are usable for the transponder ping in the same way as for a leg-source ping.

The transponder ping is received on a hydrophone near the ship, and the two-way elapsed time (including transponder delay) is measured by the 13th hydrophone channel.

In computing transponder-source ranges, the measured travel time of the 12 sea-spider hydrophones, including one of the bottom units for determining U, H, and D, is corrected by an amount given by

$$T_n = \frac{TT_{n,13} - [C_{n,13} - (TPR + TTP)]}{2}, \quad (23)$$

where

T_n = time correction for the nth source, $n = 1$ to 3;

$TT_{n,13}$ = elapsed time at a transponder receiving hydrophone at the surface;

$C_{n,13}$ = correction for the rise time of the transponder receiving hydrophone at the surface;

TPR = prerun time set into the control panel of POSDETS;

TTP = transponder internal delay, interrogation to response.

The overall measurement accuracy using these transponders will be relatively poor. The reason for this is the low acoustic frequency of the particular interrogation transducers available. The transponder interrogation frequencies are 350, 400, and 450 Hz. With a narrow-band filter in the receiving system, there is a long rise time and thus a cycle ambiguity in TTP, the internal delay. This ambiguity cannot be measured with the transponder in place and can easily be 1 or 2 cycles or 12.5 to 25 feet.

HARDWARE AND CIRCUIT DESCRIPTION

The majority of the components used in the position-determining system is digital-card logic based on NAND gates. The control, clock, and detector portions use available cards and hardware of the discrete type having a logic "1" level of -6 volts. The data-storage and output-control portions use integrated-circuit cards for compactness. The logic 1 level of these cards is +5 volts.

Appendix F comprises the three complete schematics for the position-determining system. Figure F1 contains the control and clock logic; Fig. F2 contains the preset-number gating, signal detector, and miscellaneous control or signal circuits; Fig. F3 contains the data-storage and readout circuits.

Figure 8 shows the relay rack in which the entire system, except for the oscillograph, power amplifier, and computer, is mounted. Only the POSDETS and its output panel, a test-signal generator, and the power supplies are visible in the figure. Figure 9 is a closeup of the control, preset-number, and input/output panels. Note the visual display: Ping 015, leg 3, mode 5, source 1, hydrophone 00, and travel time 0150.0 ms. Leg refers to the array leg which is being measured and is correlated with the mode. Source refers to the source from which the ping will be transmitted.

Figure 10 shows the front panels open and the wiring of the libraries. Also seen is the buffer-amplifier-filter panel for the 13 hydrophone channels. Figure 11 shows the rear of the rack and the interconnecting cables. Figure 12 shows the controller and computer racks of the Bunker-Ramo computer which was assigned to this system for the Pacific-Sea-Spider project.

The location of all of the logic cards is given in Appendix B, along with the primary function(s) of each card or of its components. Of course, particularly with gate cards, one or more of the gates can be used in other than the function specified. Cabling functions are given in Appendix C.



Fig. 8—Relay rack

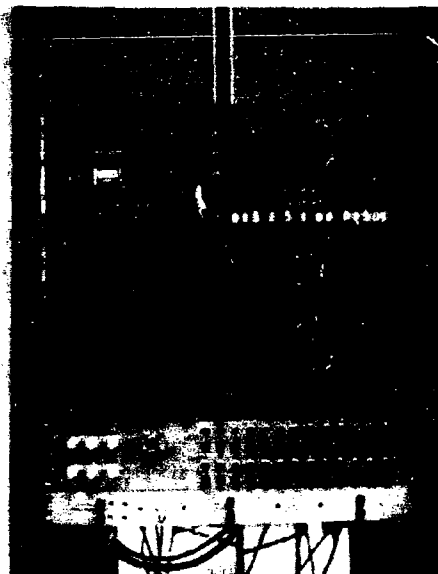


Fig. 9—Control, preset-number, and input/output panels.



Fig. 10—Open front panels and wiring of the libraries

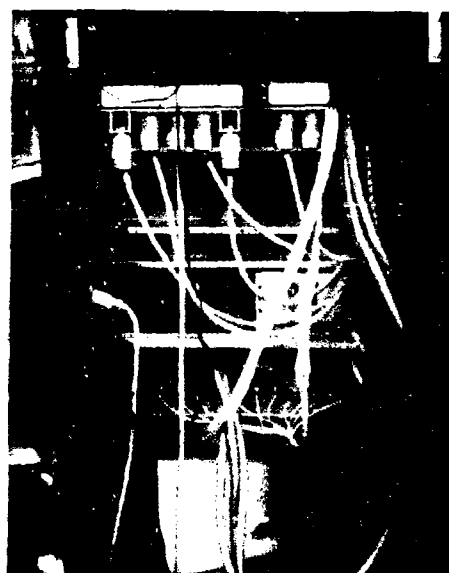
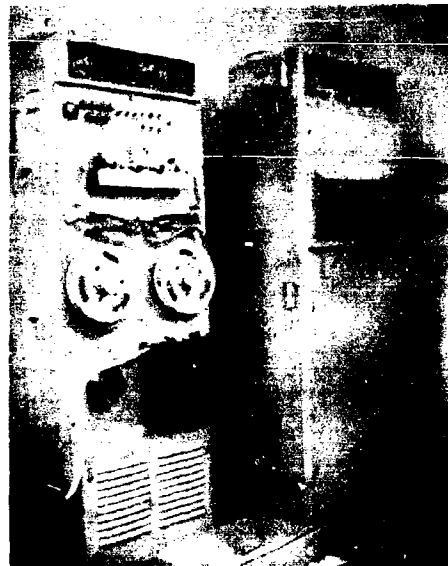


Fig. 11—Rack rear and interconnecting cables

Fig. 12—Bunker-Ramo computer



The operation of the signal detectors was explained in the theory section and will not be repeated. The operation of the controller and counter will be explained with the aid of the block diagram (Fig. 5b), the schematics in Appendix F, and the timing diagram given in Fig. 13. The logic type used in this part of the system is the NAND gate, with -6 volts or open being a 1 and 0 volts or ground being a 0.

Starting

The starting of the system must be synchronized to the 1-kHz acoustic signal. This is accomplished by squaring the sync signal* (a) and gating it with a flip-flop signal (f). The flip-flop signal is clocked on by the positive-going level (d) of a one-shot multivibrator which is used to delay the acoustic signal so that it is in the middle of the telemetry-transmitter on-time. This one-shot is triggered by either the manual button (b) or by a recycle signal (c,E) from the rest of the controller. The same signal (b or c) also triggers the one-shot to generate a turn-on gate (e) for the Pacific Sea-Spider telemetry transmitter.

The gated sync signal ($\overline{a \cdot f}$), when going positive, triggers a flip-flop (g), which enables a gate, allowing the next positive-going sync signal (a) to be passed as a start signal (h or stt) to turn on the control flip-flop of the rest of the system. The positive-going transition of the inverse of this signal (\overline{h}) triggers a flip-flop (k) to lock out the synchronizing signal until the entire start system is reset either manually or by the inverse recycle signal (c).

*Letters in parentheses refer to the signals shown in Fig. 13.

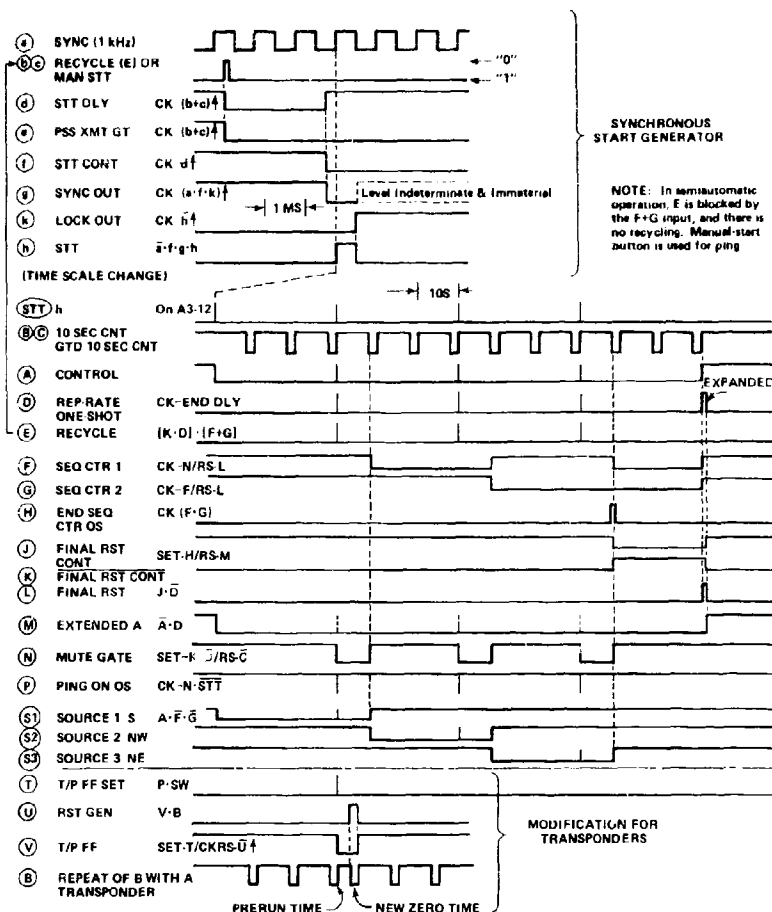


Fig. 13—Controller logic timing for the full-automatic, S1/S2/S3 mode

The manual start signal (b) is generated by a pulse generator controlled by the push-button and is inhibited by the control flip-flop (\bar{A}) while the time counter is running. A green pilot light (part of the start pushbutton) indicates "Ready" when the inhibit \bar{A} is removed, the time counter is stopped, and the system is ready to operate.

Control

The control flip-flop output (A) enables the 2-MHz master-clock oscillator signal and the 10-kHz clock signal (A6-6)* to the time counters. It is also tied to the run pilot light in the start pushbutton and gates out the sequence counter in the S1/S2/S3 mode to indicate which source is transmitting and to select the appropriate mutes.

*See Appendix F schematics.

In the manual mode of operation the control flip-flop (A) also places a reset level on the time clock and the mute-gate flip-flop when the control turns off.

The control flip-flop inverse signal (\bar{A}) is used by gating with the in-cycle reset (D) to extend itself (M). This allows the final-reset control flip-flop to be held on, preventing the in-cycle reset (D) from becoming a recycle signal (E) and enabling it to become a final reset (L) for the sequence (source) counter. More about this later. This signal (\bar{A}) also is ORed with the mute gate (N), which is on during an automatic sequence even when the signal (A) is off, to drive the INSEQ pilot light on the stop-and-manual-reset pushbutton.

The stop-and-reset button, when pressed, turns off all circuits and resets all counters, etc., to the ready state at the start of a sequence. A gate (A3-6) is used to provide such a signal at power turn-on to normalize the system.

The 10-s-period count from the time counter (B) is inhibited either when in manual mode or when a transponder has been selected (\bar{V}), until the prerun time has expired. If neither of these are present, the positive transition of the gated and inverted time signal (C) advances the delay-time (or 10-s) counter. The inverse signal (\bar{C}) resets the mute-gate flip-flop at 8 s and the sync-start section as well.

At the end of the preset delay (pulse-repetition-rate/delay-to-ready switch) an output triggers a repetition rate one-shot (D). This level is used in any of the automatic modes to reset the control flip-flop to the off state. It (D) is ORed with the manual-stop-and-reset signal and the differentiated manual-mode reset (A) to yield the in-cycle reset, which directly resets the storage system and the data readout, all the counters except the sequence (source) counter, and the prerun stages of the time counter. The in-cycle reset also is ANDed with the inverse control signal (\bar{A}) to produce M. This latter signal (M) is essentially \bar{A} extended by D and controls the final-reset flip-flop.

The inverse level (\bar{D}) is ANDed with the final-reset flip-flop level (J) to produce, after the entire sequence is completed, the final reset (L), which resets the sequence (source) counter. It (\bar{D}) is ANDed with K in two gates. One of these yields a set signal for the mute-gate flip-flop, turning it on prior to the acoustic ping in automatic modes. The other gate also includes a signal level from the sequence counter and the FULL-AUTOMATIC switch to derive the recycle start signal (E).

There are five modes of operation, determined by a front-panel switch, for the position-determining system. These are: 1, a manual mode in which the source to be used is hand-selected and a ping on that source is sent for each push of the start button; 2, 3, 4, automatic modes in which a particular source is selected, and with a push of the start button, three pings are transmitted on that source; and 5, an automatic mode in which a push of the button sends out a sequence of signals on the south, northwest, and northeast legs, one at a time, in turn.

In addition, as explained earlier, capability for full or semiautomatic operation is included. In fully automatic operation the (F + G) line is left open and provides a permanent enable to the K - \bar{D} gate. Thus each time the delay time between signals is reached, \bar{D}

generates a recycle signal (E) which restarts the system, except when the third ping has been transmitted. Then signal H, which indicates the end of sequence, changes the state of K. Because this state is only changed back by M (extended \bar{A}), the last reset (\bar{D}) will be blocked and will produce no recycle signal (E).

In semiautomatic operation, there are two things which can happen. In the S1/S2/S3 mode a ground level from the mode switch placed on gate A8-23 places an inhibit on the gate generating the E signal, and no recycling occurs. Thus at the end of the delay-time count the system will pause, with the control flip-flop off and all other circuits ready to go in their normal spot in sequence. The effect in Fig. 13 will be to remove the E pulses and lengthen the interim off-level of A. A push of the start button then sends out a ping on the source which had been hand-selected at the Pacific Sea-Spider computer console. In any of the three modes for three pings on one source, the 0 state of the sequence counter is used to inhibit E in the same way as the switched ground. After the 0 state (the first ping), however, the inhibit is removed, and the recycle signal (E) sends out the three pings automatically.

The acoustic ping is initiated by the ping-gate, one-shot output (\bar{P}). This one-shot is triggered in one of two ways. In the manual-operation mode, the signal from the control flip-flop (A) is switched to an inverter, and the inverted signal, after differentiation, is used to trigger the ping at the beginning of the control-on state. In the automatic modes the triggering signal is a result of ANDing the mute gate (N) and the inverse start (\overline{STT}). In either case, the ping begins in synchronization with the start signal to within a few microseconds.

The ping one-shot output (\bar{P}) sets a flip-flop which, after level shifting, is used to gate on the Pacific Sea-Spider acoustic signal. This flip-flop is reset by a gated signal from the time counter. If no transponder has been selected, the reset occurs at 8 ms after the start. If a transponder has been selected, reset will occur at 80 ms. The transponder itself is set to produce a 10-ms ping.

The ping one-shot output (\bar{P}) also serves other functions. It is used as an input to the oscillograph-control circuits to normalize them, thus indicating that a ping has been sent. It (\bar{P}) is ORed with the manual-stop-and-reset function to produce, after gating with the transponder-state output, the regular counter reset or the transponder prerun time in the appropriate time-counter stages. In other words, if a 6-s prerun time is desired, the last two decades of the counter are set to provide a count state of 4000.0 ms, instead of 0.0 ms. Preruns are provided in 500-ms intervals from 3500 to 6000 ms inclusive.

The other output of the ping one-shot (P) is used to turn on a transponder-control flip-flop if that flip flop is switched on at the control panel.

The mute-gate signal (N) is used to drive the sequence counter. This counter starts in the 00 state, calling for S_1 . Eight seconds after a ping, the counter advances, first to 01, calling for S_2 , then to 10, calling for S_3 . After the third ping the counter advances to 11. This state is detected and triggers the end-of-sequence flip-flop (H). The latter sets the final-reset flip-flop to block E, N, and P and to enable L.

Each of the first three states of the sequence counter is gated out when the control flip-flop (A) is on if the mode switch is not on one of the conditions of three pulses on one source (S1, S2, S3). After inverting and ORing with the mode switch of one source and three pulses are to be used, the resulting level is usable for automatic source selection. In this case, where such source selection is unavailable, these levels are used to select the proper transponder when a transponder is called for by the proper control-panel switch.

These same levels are then gated by the mute gate signal (N). When the mute gate is triggered by $\bar{D} \cdot K$, it gates out the three levels in such a way as to yield a negative on the \bar{S} line and a positive on the S line if in state 0 (source 1). These latter states control the proper preset-number mute times. Until an end-of-delay ($\bar{D} \cdot K$) occurs, the mute gate signal (N) serves as a general mute and after double inversion as three mutes S, NW, and NE.

The positive on the S line referred to above is fed through part of the Pacific Sea-Spider mode switch. If in modes 1 or 2, in which the S leg is being measured, this positive level is buffered and used as the up-leg mute, while inverted, it enables the cross-leg line. In modes 3 and 4 the NE source line is monitored and when positive produces the up-leg mute, and in mode 5 the NW source does the same.

A further word about muting. Table 5 gives the estimated travel times (using the ray-trace program for average velocity previously mentioned), the proposed preset times (when the mute would be removed), and the assigned number for that time for both up-leg and cross-leg measurements. From this table one can see that each mode, which will have a particular set of hydrophones associated with it, and the type of measurement, up- or cross-leg, will determine what preset number should be applied to which hydrophone detector.

Table 6 associates the hydrophone depth, hydrophone number, and measurement mode with the preset number to be used. The gating, which occupies most of Fig. F2, accomplishes this. The left half of Fig. F2 shows the gating for the 14 preset numbers and for the up- and cross-leg start times and the up- and cross-leg stop times for the oscillograph. The up- and cross-leg mutes are used to select: (a) the sets of preset numbers which will be generated (numbers 3 to 6 in up-leg measurements only, and number 8 in cross-leg only), and (b) the correct preset number as a function of up- or cross-leg and to assign the correct number to the correct hydrophone.

The other mute sets (S, NW, NE, \bar{S} , \bar{NW} , \bar{NE} , and general) are also used in selecting the correct number for the correct hydrophone and, in the case of the general mute, in preventing the preset number from reaching the signal detectors if the system is not in an active-hydrophone interval.

The Pacific Sea-Spider design does not always assign the same hydrophone to the same telemetry channel. Thus relay switching is provided to switch the telemetry channel, if required, to the correct hydrophone-signal detector in the case of hydrophones 4 to 7 and 9 to 12.

The rest of the circuits on Fig. F2 are details of nonstandard circuits built on the blank cards of the ping counter. Each ping trigger (P) advances the ping counter. A sample of the time-marker output is given in Fig. 14.

Table 5
Pacific Sea-Spider Estimated Travel and Mute-Removal Times
For All Conditions

Hydrophone Depth (ft)	Up Leg			Cross Leg		
	Estimated Time (ms)	Preset Time (ms)	Preset Time Generator Number	Estimated Time (ms)	Preset Time (ms)	Preset Time (ms)
150	5205.0	5150	10, 11	5211.9	5200	11
300	5164.3	5150	10, 11	5202.0	5150	10
2500	4529.7	4450	7	5079.3	5050	9
2515	—	4450	7	—	5050	9
2538	—	4450	7	—	5050	9
2572	—	4450	7	—	5050	9
2623	4492.0	4450	7	5074.2	5050	9
3000	4384.0	4350	6	5060.4	5050	—
6000	3513.9	3500	5	5027.1	5000	8
10,000	2363.9	2300	4	5197.4	5150	10
10,015	—	2300	4	—	5150	10
10,072	2342.0	2300	4	5202.5	5150	10
10,500	2097.0	2050	3	5234.8	5200	11
13,000	1511.7	1500	2	5470.3	5450	12
16,000	668.4	650	1	5845.3	5800	13
18,400	—	—	—	6203.1	6150	14
Start†	—	250ms	—	—	4500ms	—
Stop†	—	5500ms	—	—	6200ms	—

†These refer to the oscillograph control.

The time input to the mixer is generated (Fig. F1) in three gated flip-flops (B8). The first is reset at 0.5 ms set at 1.0 ms and yields a time-symmetrical, 1-ms-period square wave. This 1-ms signal resets the second flip-flop, which is set every 10 ms. Thus the output of the second flip-flop is an 0.5-ms pulse occurring every 10 ms. The third flip-flop is set every 100 ms and reset 4 ms later. The preset-number (mute-removal) pulses and the signal-detected pulses are also inputs to the mixer.

Time Counter

The time counter consists of five stages of BCD-coded, divide-by-10 units with a 10-kHz clock input. The first three stages are of normal design. The last two stages, however, are modified so that they can be reset to a number equal to 10 minus the set prerun time for the transponder, e.g., for a prerun time of 4.5 s, the last two stages are preset to 5.5 s when

Table 6
Pacific Sea-Spider Preset Number to Hydrophone Correlation

Hydro- phone Depth Level (ft)	Mode One			Mode Two			Mode Three			Mode Four			Mode Five		
	Hydro- phone Number	Up Preset Number	Cross Preset Number	Hydro- phone Number	Up Preset Number	Cross Preset Number	Hydro- phone Number	Up Preset Number	Cross Preset Number	Hydro- phone Number	Up Preset Number	Cross Preset Number	Hydro- phone Number	Up Preset Number	Cross Preset Number
Leg Measured	S	S	S	S	S	S	NE	NE	NE	NE	NE	NE	NW	NW	NW
150	-	-	-	-	-	-	210	10 or 11	11	210	10 or 11	11	310	10 or 11	11
300	110	10 or 11	10	110	10 or 11	10	-	-	-	-	-	-	309	10 or 11	10
2500	109(304)	7	9	109	7	9	209	7	9	209(308)	7	9	308	7	9
2515	108(208)	7	9	108	7	9	208	7	9	208	7	9	-(209)	7	9
2538	-	-	-	-	-	-	207	7	9	207	7	9	-(207)	7	9
2572	107	7	9	107	7	9	206	7	9	206(107)	7	9	-	-	-
2623	-	-	-	-	-	-	205	7	9	205	7	9	-	-	-
3000	106	6	9	106	6	9	204	6	9	204	6	9	307	6	9
5000	-	-	-	-	-	-	-	-	-	-	-	-	306	5	8
10,000	105	4	10	105	4	10	203	4	10	203	4	10	305	4	10
10,015	104	4	10	104	4	10	-	-	-	-	-	-	-	-	-
10,072	103	4	10	103	4	10	-	-	-	-	-	-	-	-	-
10,500	102	3	11	102	3	11	202	3	11	202	3	11	304	3	11
13,000	-	-	-	-(303)	2	12	-(303)	2	12	-	2	12	303	2	12
16,000	-	-	-	-(302)	1	13	-(302)	1	13	-	1	13	302	1	13
18,400	101	-	14	101	-	14	201	-	14	201	-	14	301	-	14

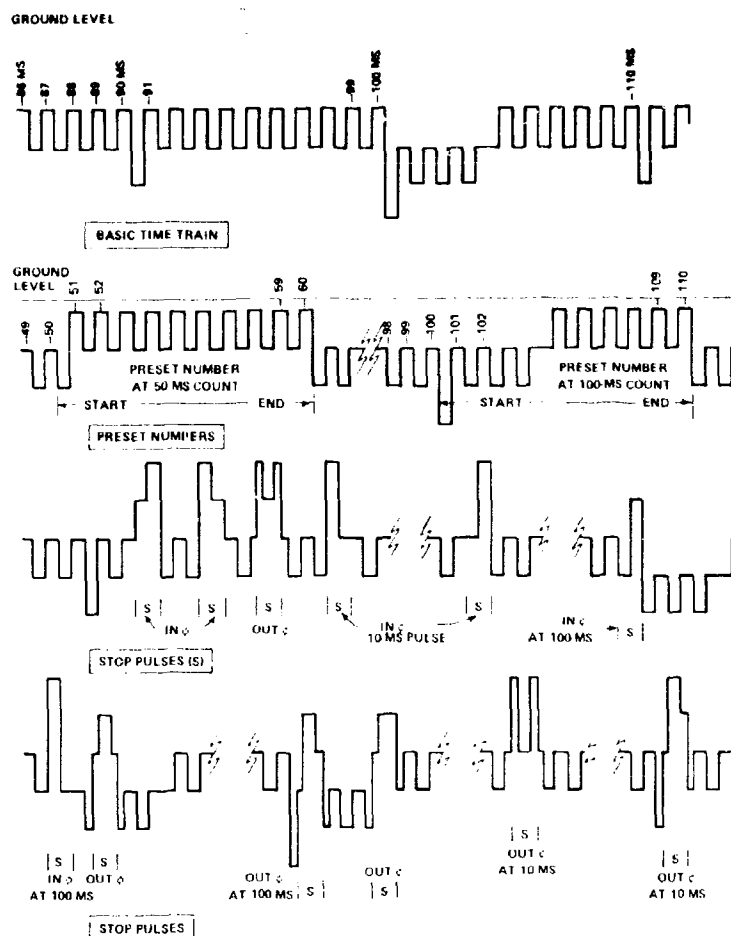


Fig. 14—Sample waveforms of the time/mark output

desired instead of to zero. Besides the individual BCD bits to the time storage register, the counter also provides a 10-s-period waveform which, after gating with the transponder state, provides the control flip-flop reset in the manual mode. The 10-s-period waveform also resets the transponder flip-flop when the zero count is reached at the end of the prerun time and is used to develop the end-active-hydrophone (\bar{C}) and delay-time clock (C) signals.* Waveforms having periods of 8 ms and 80 ms are used to reset the acoustic-signal gate at the proper time, depending on the state of the transponder flip-flops.

*Capital letters refer to the signal shown in Fig. 13.

Data Storage and Readout

Data Storage. The operation of this part of the system is described using the block diagram, Fig. 5b, the timing diagram, Fig. 15, and Fig. F3. The logic type used in this part is the NAND gate with +5 volts or open being a "1" and 0 volts or grounded being a "0." The travel-time data-storage registers consist of input level converter-buffers for the time bits, the read-command lines, the in-cycle-reset line (A6, 12, 18, 24, B30, 32), and storage registers detailed in Fig. 16 (A1, 3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25, 27, 29, 31, 32). Readout and control systems will be described later.

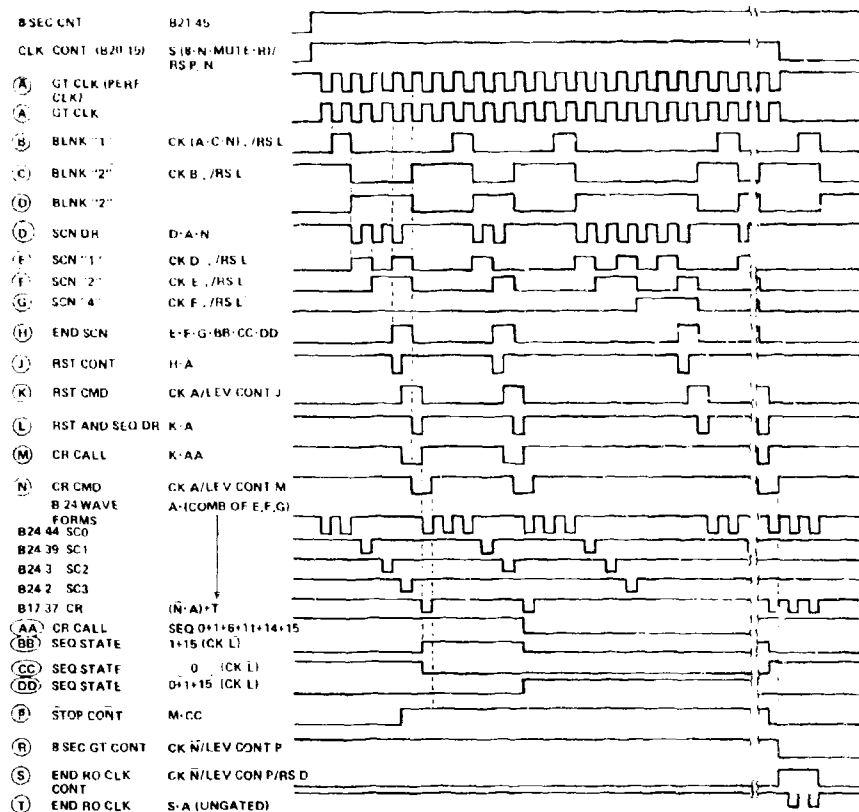


Fig. 15—Data-readout logic timing for fully-automatic display

The basic storage block of Fig. 16 is for one decimal digit of one hydrophone-detector channel. Since five decimal digits are recorded, five of these basic blocks are required per hydrophone channel. For the 13 channels of this system, 65 basic storage blocks are required. There are four such blocks on each logic card, so 17 cards are required.

These storage blocks are arranged primarily for the 12 Pacific Sea-Spider hydrophones and use parallel-data entry. Each binary bit of a decimal digit uses one of the flip flops of the

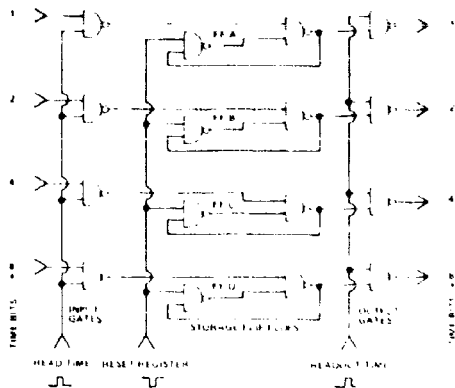


Fig. 16 Data-storage element, one decimal digit

four available in each basic storage block. Thus the 0.1-ms bit of the tenths of a millisecond digit occupies the A flip-flops of cards 1, 3, and 5; the 0.2-ms bit is on flip-flop B; etc. Cards 1, 3, and 5 store all the bits of the tenths of a millisecond digit of the 12 PSS hydrophones, cards 7, 9, and 11 store all the bits of the millisecond digit of the 12 hydrophones, etc.

The five read-time lines associated with all the digit-storage blocks for each hydrophone are tied together. A 1 on this line reads into the storage flip-flop the 1 states of all 20 bits of time information.

Likewise, all five readout-time lines of the same digit-storage blocks are tied together, and a 1 on the line will read out the state of the 20 storage flip-flops in parallel. During reading of data, one or more than one read line can be active at the same time. The readout-control system, however, assures that only one of the readout lines of the 13 available is activated.

All the bits for hydrophone 13 are stored on cards, A31 and A32; 16 bits are on A31, and four are on A32. Operation is the same as for the 12 PSS hydrophones.

The time-bit-output lines, 260 in number, are fed to 16-input OR gates for combining to one 20-bit set of lines. The BCD data for ping number, source activated, and mode in use are also inputs to these OR gates. Their function is to take 16 input data words of up to 20 bits and combine them, one at a time, into one word of up to 20 bits, which is then used for visual display of time, etc., on the control panel and is available for scanout to the paper-tape perforator.

Data Readout. The 20 bits of the words that are available, one word at a time, at the output of the OR-gate combiner are fed to AND gates and are read out, four bits in parallel at a time, in six sequenced scans (one scan is allowed for the decimal point) to an OR-gate-buffer/level-converter. For example, if the time stored in the data-storage register for H_1 is 1248.7 and hydrophone 1 readout is called, then the BCD number 0001 0010 0100 1000 0111 is available for read-out. The scan control circuits will gate out in sequence: 000001, 000010, 000100, and 001000. A code for a decimal point (011011) is then inserted on the output lines, and the final 000111 will be gated out. Appropriate codes for blanks (110000) and carriage returns (101010) are generated as required.

Clock and Clock Control. The tape perforator used in the system is made by the Tally Corporation and is a duplicate of the one in the Bunker-Ramo computer. It has a minimum clock period of 16 ms. Therefore the 10-ms bit-time line, which has a 20-ms period, is used to develop the scan clock for the readout (A or T) after gating by the control flip-flops.

The scan-clock control flip-flop output is reset to ground by the in-cycle reset from the system controller (D) or by the manual stop-and-reset. Eight seconds after a ping has been sent, all data should be stored in the register. The 8-s time bit is then used to set the scan clock-control flip-flop if (a) the carriage-return (CR) control (N) is positive (it should be, after a reset), (b) the full-scan sequence has not been completed (level R), and (c) no mute for a transponder is being received from the system controller. The set scan-control flip-flop (CLK-CONT, Fig. 15) allows the clock frequency to pass (A) until the flip-flop is reset. This occurs at the end of the total scan/sequence when the stop control (P) is positive at the same time that the CR control (N) goes positive (\bar{N} , the clock for this control flip flop, goes negative).

This same end-of-scan/sequence also sets the extra-clock flip-flop (level S), gating out two extra clock periods (T) for data-block spacing. The extra-clock flip-flop is normalized by the reset pulses and by the second stage of the blank counter (D).

The reset pulses normalize the 8-s gate-control flip-flop (R). The end-of-scan/sequence sets this flip-flop and blocks the 8-s turn-on signal until an in-cycle or manual reset occurs. This prevents extra data readouts when delay times between pings longer than 10 s are in use.

Blank and Carriage Return Control. When the in-cycle or manual reset from the system controller occurs, the reset and carriage-return flip-flops are normalized, and the 2-stage blank, 3-stage scan, and sequence counters are reset.

The CR control level (N) in the normal state gates on the clock to the blank and scan counters. However, the blank-counter level (D) blocks the clock from the scan counter. Thus the first two clock periods produce two counts (B and C) on the blank counter while the scan counter in the 0 state gates out the two clock pulses onto the blank generation line (B24-44). The latter inserts a 1 on the "32" line of the tape perforator, and, if there is no CR called for (N normal), a 1 on the "16" line, yielding the code 110000 for blank.

After the second pulse the blank counter (C) blocks itself from further counting, and the inverted signal (D) gates the clock into the scan counter (D'). The latter, for each state advanced, gates out one clock pulse to the proper set of four readout-bit gates for a decimal digit to the tape perforator. Thus in state 1 the scan counter gates out the four bits of the thousands digit; in state 2, the four bits of the hundreds digit; etc., with fifth state generating the decimal point.

The scan counter state of three bits is also fed to three AND gates along with the sequence-counter gated outputs to determine the number of digits to be scanned out. Thus at the start of a sequence, the sequence counter will be in the 0 state, calling for a ping number, and line CC will be positive. This (CC) will gate out the "3" state of the scan counter (H) at the time that the third digit is gated out. This end-scan output (H) initiates

the scan-reset/sequence-advance cycle. In the number-1 and number-15 sequence states, the end-scan signal (H) is generated by a signal (BB) at the time the second digit is read out. In all other states, 2 to 14, the end-scan signal (H) is generated by the signal (DD) at the sixth count of the scan counter, which corresponds to the readout of the fifth digit. As soon as the scan counter resets, the end-scan signal H is restored to normal.

The end-of-scan signal (H) is gated by the inverse clock (\bar{A}) to yield the control signal (J) for the reset flip-flop. The latter signal (J) is clocked into the reset flip-flop by the inverse clock (\bar{A}) to produce the reset command (K). The latter, also gated by the inverse clock (\bar{A}), then becomes the scan- and blank-counter reset (L and L') and when inverted is used to clock the sequence counter for computer (automatic) operation. The next clock pulse will reset the reset flip-flop, because the end-scan level (H) will be back to normal.

The reset command is gated with a CR call (AA) which is generated by the sequence counter in states 0, 1, 6, 11, 14, or 15 to indicate the need for a carriage return. The resulting CR-call signal (M) is clocked into the CR flip-flop by the clock (A) and yields the CR-control signals (N and \bar{N}). These are normalized by the succeeding clock pulse, because the reset-command level (K) will have been normalized.

If a CR-command signal (N) exists, it blocks both the scan and blank counters for the one clock period that it exists. It also blocks any start pulses from the system controller during the carriage return. The inverse CR command (\bar{N}) is gated out by the clock to enable the "2"- and "8"-output bit lines and disable the "16"-bit line which would otherwise be produced by the blank generator. The latter produces the enable signal on the "32" line, yielding a total output of 101010, a carriage-return code. After the one clock period used for carriage return, the regular two counts for blanks followed by the scan count will occur.

The inverse CR command (\bar{N}) also serves as the clock (at the trailing edge) for the clock-control flip-flops, which will be clocked off at the end of the entire scan/sequence cycle when the sequence counter returns to the 0 state.

The 0 state of the sequence counter (CC) is provided by an inverter. In addition to controlling the number of digits being read out (H, J, K), this signal (CC) is also gated with the CR call (M) to obtain the stop-command signal (P). Thus in the beginning of a sequence the zero state (CC) is inhibited and removed by the CR call (M) before the CR-command (N) occurs. By this means the clock-control flip-flops do not change state.

When the sequence counter goes from the 15 state to the 0 state at the end of a sequence, however, the stop control (P) will go positive as the CR call (M) is normalized. Since the CR-command (N) logs the call, its inverse (\bar{N}) will clock in the stop control (P), remove the clock (A), block the 8-s start via signal R, and, if the dashed modification is installed, enable the end-readout clock control (S).

This will gate out end-readout clock pulses (T), which are ORed with the regular clock-pulse line to drive the blank counter. After two clock pulses the second-stage, blank-counter output (C) will normalize the end-readout flip-flop and stop the clock pulses (T).

These same two end-readout clock pulses are used to override the CR and blank outputs of the scan generator and cause generation of the 101010 carriage-return signal. The result is an extra pair of carriage returns for separation between each block of data from one source.

Another modification which can be used, modification A, is to start the readout process at 7 s instead of 8 s. Since the complete scan/sequence process takes a bit more than 2 s, a new ping cannot be transmitted 10 s after the first ping, and the minimum repetition rate is 20 s. If the readout is started at 7 s, it should be finished well before 10 s, and a ping-repetition rate of 10 s is possible.

This modification requires a change in the source-number display and readout gating, however. The reset states of the sequence counter in the system controller are level shifted (B30) and gated to provide for visual display of the source number in use and to provide the input to the OR-gate combiner for perforated-tape readout.

Modified or not, the source number display remains the same, showing 1 for system sequence state 0, 2 in state 1, 3 in state 2 and 0 in state 3, indicating the approaching end of the cycle. If the system is modified, the perforated tape sees the state of the advanced system-sequence counter (this occurs at 8 s) and must read state 1 as 1, 2 as 2, and 3 as 3. If modified so that the readout starts before the system-sequence counter advances, the paper tape senses in the same way as the visual display.

The binary-output states of the readout-sequence counter are gated to provide a visual readout of the hydrophone channel which is to be read out, i.e., state 2 indicates 1 on the hydrophone number display.

The states of the ping-number counter are level shifted and gated out, in readout-sequence state 0, to the OR-gate combiner and the perforator. Likewise, state 15 gates out a BCD-coded mode number generated by the Pacific Sea-Spider mode switch.

A manual mode of operation of the readout is available as a backup to the tape perforator. In this mode the scan generator is not used. Instead the sequencer is either stepped by a momentary switch or is preset to a specific state by a push button and a rotary switch wired to generate the desired hydrophone-channel state. Reset of the system is obtained from the mute line from the system controller and is the same signal as the ping-initiate signal (P), the manual-stop-and-reset signal, or the transponder-on-mute signal.

RANGE CALCULATIONS

A detailed report on the computer program written in FORTRAN II for the Bunker-Ramo compiler is given in the report "Bunker-Ramo 133/141 Computer Operations Manual - Pacific Sea-Spider Motion Measurements," by M.F. Marek, to be published as an NRL memorandum report.

In general the program is in two parts. The first part of the program uses velocity-profile data to obtain average velocities for the paths involved, and the second part uses these velocities and the travel times to determine the coordinates of a particular set of hydrophones with respect to the base-reference triangle.

The average-velocity portion of the program uses a linearized approximation of the velocity-profile data. This approximation is done by breaking up by eye the velocity-profile plots, obtained from a velocimeter or Nansen cast, into straight-line segments. The number of segments to be used can be as many as required for the degree of accuracy of approximation desired. The segmented or linearized data are then used as follows.

The 16 actual hydrophone-depth levels of the Pacific Sea-Spider are read into the computer; then the number of inflection points are read in; then the velocity value and the depth

Table 7
Pacific Sea-Spider: Average Velocity and Depth Relationships

Depth (ft)	Velocity Number Associated with Depth	Hydrophone Channel Using Velocity Number
18,400	1	1
16,000	2	2, 11
13,000	3	3, 12
10,500	4	2, 4
10,072	5	3
10,015	6	4
10,000	7	3, 5
6,000	8	6
3,000	9	4, 6, 7
2,623	10	5
2,572	11	6, 7, 11
2,538	12	7, 12
2,515	13	8, 11
2,500	14	8, 9, 12
300	15	9, 10
150	16	10

Hydro- phone Channel Number	Velocity Number Associated with Hydrophone Channel	Mode of Operation	Velocity Number Associated with Hydrophone Channel	Mode of Operation	Velocity Number Associated with Hydrophone Channel	Mode of Operation
1	1	ALL				
2	2	5	4	1 to 4		
3	3	5	5	1, 2	7	3, 4
4	4	5	6	1, 2	9	3, 4
5	7	1, 2, 5	10	3, 4		
6	8	1	9	1, 2	11	3, 4
7	9	1	11	1, 2	12	3, 4
8	13	1 to 4	1	5		
9	14	1 to 4	15	5		
10	15	1, 2	16	3 to 5		
11	2	2, 3	11	4	13	1, 5
12	3	2, 3	14	1, 4	12	5

of the inflection point of each segment, starting at the bottom-hydrophone depth and ending at the surface, are read in; and finally the velocity of sound at the ocean bottom is read in.

The parameters of the base-reference triangle are computed by hand and inserted into the computer with the proper sign when called for. The data tape from the system tape perforator is read in when called for, and the time corrections in milliseconds (the number of cycles after the start of the acoustic pulse at which detection occurs) are typed in when called for. The computer then types out the XYZ coordinates for the 12 hydrophones.

If no transponder is in use, the time measured for hydrophone 13 will be zero, and nothing happens. When a transponder is in use, the travel time from surface to transponder and return is measured by hydrophone 13 and used to correct the other 12 arrival times for the difference between counter 0 and the actual acoustic ping from the transponder.

Appendix D contains samples of (a) the operating instructions for the two programs and typical typed-in responses, (b) a sample velocity-profile data tape, (c) a sample data tape from the position measuring system (typed by hand), (d) the resulting HYMO table generated from the data tape B, and (e) a sample answer page generated from data tape C and the HYMO table D.

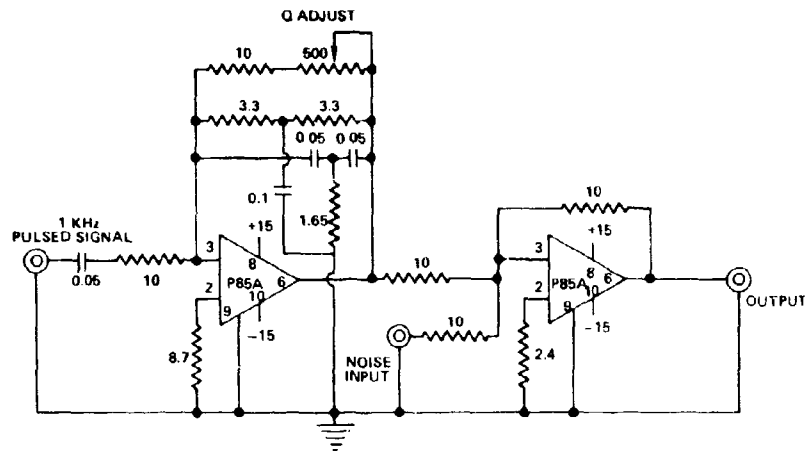
RESULTS

The position-measuring system has been tested with simulated signals. Unfortunately, since the Pacific Sea-Spider installation was not successful, no operational data have been obtained from the system. The following setup exercises and checks have been done.

The axis-crossing Schmidt triggers have been adjusted for true axis-crossing, and the level-detecting triggers have been adjusted for uniform detection level. The preset-number muting system has been checked for accuracy and proper switching. A simulated signal, with and without noise, has been checked by using simulated data tapes.

The axis-crossing detector is set up by adjusting the positive-going threshold to 0 volts, then fine adjusted by synchronizing an oscilloscope to the signal, looking at an expanded presentation of the axis-crossing at the end of one cycle of signal, and adjusting the threshold for no change in the axis-crossing position as the signal is attenuated by 20 db. The limit of shift was arbitrarily set for ± 2 percent of the period, equivalent to about ± 0.1 ft.

The detection circuits have been checked with the aid of a pulse-train generator and the signal simulator shown in Fig. 17. The filter in the position-measuring system and its bandpass characteristics are shown in Fig. 18, and the buffer-isolation amplifiers are shown in Fig. 19. The minimum detectable signal-to-noise ratio with 20-kHz band noise was -3 db. Converting to the 1-kHz band-limited noise of the original Pacific Sea-Spider system yields a minimum detectable signal-to-noise ratio of +10 db at the output of the telemetering system. Actual capability may be slightly better, as the criteria used were virtually no noise detection and 100 percent signal detection.



Note: All capacitances are in μF ; all resistances are in $\text{k}\Omega$; all voltages are in V.

Fig. 17—Acoustic-signal simulator

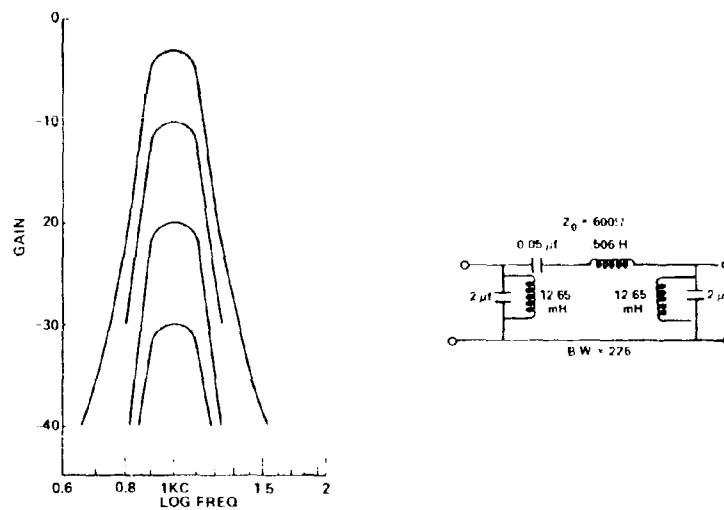
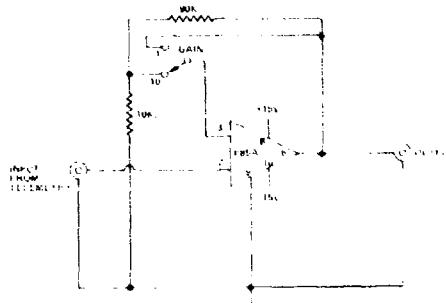


Fig. 18—Bandpass filter and characteristics

Determining the actual cycle at which detection occurred in the minimum signal-to-noise condition will be difficult. However, although this was not done with the simulated signal, it should be feasible. As signal-to-noise ratio improves, the ease of determining the actual cycle of detection will increase rapidly.

Fig. 19—Buffer amplifier



CONCLUSIONS AND MODIFICATIONS

The system described in this report is a control and time-measuring system which, when used with three acoustic sources at known locations, will measure the travel-times from the three sources to up to 12 hydrophones. The computer program developed with the system enables the position of these hydrophones relative to the source positions to be determined.

The time measurement is a phase measurement after level detection. Thus, if very short rise times and sufficient signal-to-noise ratios are involved, such that the first negative half-cycle can be detected, the system has a time resolution of ± 0.1 ms, equivalent to about ± 6 in. position uncertainty. If the sources are high-frequency sources with reasonable rise times, repeatability of a fixed-time measurement will also be ± 0.1 ms.

With low-frequency sources such as those of the Pacific Sea-Spider (1 kHz), a resolution of ± 0.1 ms requires recording the signals on an oscillograph and visually determining the cycle which was detected. If rise times are about 1 to 3 cycles, the axis-crossing detection should not shift more than 1 cycle, and a repeatability of ± 2.5 ft should be obtainable without visual readout of the detected cycle.

Accuracy of absolute position should be about 0.1 per cent or better, as the time-interval clock is crystal controlled. The best accuracy capability will be primarily a function of the accuracy of the velocity-profile data and its linearization.

Modifications are possible on both the system and the program. System modifications which are feasible include using accurate time starting of the system to coincide with accurately timed, free-running pingers as sources. Locations of such pingers to establish the reference triangle may be difficult, however. Also the delay counter may be modified from its present 10-s increments to lesser time increments if shorter ranges are being measured. Care must be taken to change other timed signals, such as the one which generates level C in the controller, in the system if this is done.

Modifications to the program would include one to allow a fixed detection delay of 1, 2, 3, etc. ms, as required, if there is sufficient stability in the acoustic signals, rather than the current typed-in corrections used for each hydrophone. Also, calculation of movement from previous positions may be a desirable addition.

APPENDIX A
Pacific Sea-Spider Modes and Active Hydrophones*

Hydrophone Depth (ft)	Mode				
	1	2	3	4	5
150	—	—	210	210	310
300	110	110	—	—	309
2,500	109, 308	109	209	209, 308	308
2,515	108, 208	108	208	208	— , 108
2,538	—	—	207	207	— , 207
2,572	107	107	206	107, 206	—
2,623	—	—	205	205	—
3,000	106	106	204	204	307
6,000	—	—	—	—	306
10,000	105	105	203	203	305
10,015	104	104	—	—	—
10,072	103	103	—	—	—
10,500	102	102	202	202	304
13,000	—	— , 303	— , 303	—	303
16,000	—	— , 302	— , 302	—	302
18,400	101	101	201	201	301

*100 series on south leg
200 series on northeast leg
300 series on northwest leg

APPENDIX B

Position Determining System—Card Layout

Position Determining System—Card Layout

Slot No.	Computer Control Division						Library F	
	Library A Controller Top Left Side	Library B Preset Counter & Output Dr Middle Left Side	Library C PS No. & STT/STP Gating Bottom Left Side	Library D Sig Det 1 to 4 Top Right Side	Library E Sig Det 5 to 8 Middle Right Side	Library F Sig Det 9 to 13 Bottom Right Side	Cable 3 To Control Panel	
1	BP	0-1 ms Counter	BP	Cable 1 To SDS Logic	Cable 2 To SDS Logic	Cable 3 To Control Panel	ST	H9,00 Lev and Axis
2	—	Rly Driver	—	H1,0 Lev and Axis Det	H15 Lev and Axis	—	DL	9 Sig
3	D1	SYNC Start Gating	DN	H11 Sig Gating	5 Sig	—	BC	9 Det
4	BC	SYNC (2)/Ping Control	PC	H11 Det and Control	5 Det	—	DN	H9,10 Read
5	BC	Rep Rate Ctr (3)	DN	H11,2 Read Gating	H15,6 Read	—	BC	H10 Det
6	D1	Control Gating	DC	H12 Det and Control	H16 Det	—	DL	10 Sig
7	BC	Seq (2)/Rat Gen (1)	D1	H12 Sig Gating	6 Sig	—	ST	10 Lev and Axis
8	DL	Control Gating	D1	H12 Lev and Axis Det	6 Lev and Axis	—	—	—
9	DM(O.S.)	End Rep/End Seq/Ping	DN	—	—	—	BP	H9-12 Analog Gates
10	DL	Sequence Gating	DC	H11,4 Analog Gates	H15-8 Analog Gates	—	—	—
11	D1	T/D Control Gating	DN	—	—	—	ST	H11 Lev and Axis
12	DN	Misc Gating	DC	H13 Lev and Axis	H17 Lev and Axis	—	DL	11 Sig
13	PN	Mute (3)/Rat Buffer	DL	H13 Sig	7 Sig	—	BC	11 Det
14	LD	Pilot Lamp Drivers	DC	H13 Det	7 Det	—	DN	H11,12 Read
15	—	—	DC	H13,4 Read	H17,8 Read	—	BC	H12 Det
16	—	—	DN	H14 Det	H18 Det	—	DL	12 Sig
17	D1	T/P Input Cont Gates	—	H14 Sig	8 Sig	—	ST	12 Lev and Axis
18	BC	T/P Select Control	D1	H14 Lev and Axis	8 Lev and Axis	—	ST	H13 Lev and Axis
19	DL	T/P Output Gating	—	—	—	—	DL	13 Sig
20	—	—	—	—	—	—	BC	13 Det
21	BC	Ping Counter	—	—	—	—	RV	13 Read
22	BC	Ping Counter	PS	Op Amps PS for	Relay Driver	—	DN	13 Analog Gate
23	BC	Ping Counter	PS	Sq and Hyd Buffers	—	—	BP	—
24	D1	T/P and Control Gating	Cable 4	To Control Panel	Time-Mark Mixer	—	—	—
25	Cable 7	To Control Panel	Cable 5	To Control Panel	—	—	—	—

Position Determining System—Card Layout (Continued)

Scientific Data Systems			
Slot	Library A		Library B
	Data Storage & Readout		Readout Control & Misc.
1	FJ-13A	0.1-ms Decade Time Storage (DTS)	SDS Power Supply
2	LJ-17A	0.1- and 0.2-Bit Combiner	SDS Power Supply
3	FJ-13B	0.1-ms DTS	SDS Power Supply
4	LJ-17B	0.4- and 0.8-ms Bit Combiner	SDS Power Supply
5	FJ-13C	0.1-ms DTS	SDS Power Supply
6	NT-18a	Time In-0.1-ms + 1-ms/Hydro Read 1-3	SDS Power Supply
7	FJ-13D	1-ms DTS	SDS Power Supply
8	LJ-17C	1- and 2-ms Bit Combiner	SDS Power Supply
9	FJ-13E	1-ms DTS	SDS Power Supply
10	LF-17D	4- and 8-ms Bit Combiner	SDS Power Supply
11	FJ-13F	1-ms DTS	SDS Power Supply
12	NT-18b	Time-in-2, 4, 8, 10, 20/Hydro Read 4-6	SDS Power Supply
13	FJ-13G	10-ms DTS	SDS Power Supply
14	LJ-17E	10- and 20-ms Bit Combiner	SDS Power Supply
15	FJ-13H	10-ms DTS	SDS Power Supply
16	LJ-17F	40- and 80-ms Bit Combiner	SDS Power Supply
17	FJ-13N	10-ms DTS	SDS Power Supply
18	NT-18c	Time in -40, 80, 1, 2, 4 x 100/Hydro Rd 7-9	Scan out 1000's/Scan out CR, BNK and DP
19	FJ-13K	100-ms DTS	Scan out other time digits
20	LJ-17G	100- and 200-ms Bit Combiner	Lev Conv and final punch drive
21	FJ-13L	100-ms DTS	Clock gen and control FF
22	LJ-17H	400- and 800-ms Bit Combiner	Scan and Seq Control Gating/Displ Gates
23	FJ-13M	100-ms DTS	Scan and Seq Control Gating/Displ Gates
24	NT-18d	Time in -800, 1, 2, 4, 8 x 1000/Hydro Rd 10-12	Scan Ctr (3)/Blink Ctr (2)/Scan Control
25	FJ-13N	1000-ms DTS	Scan Ctr Output -Scan gate drive
26	LJ-17J	1000- and 2000-ms Bit Combiner	Sequence Counter
27	FJ-13O	1000-ms DTS	Hydro Displ and Seq Gating Misc Contr
28	LJ-17K	4000- and 8000-ms Bit Combiner	Hydro Displ and Seq Gating Misc Contr
29	FJ-13P	1000-ms DTS	Ping Ctr Lev Shift, 1's and 10's
30	LJ-14X	Stored Data Readout Drive Buffers	Ping Ctr Lev Shift, 100's/Rst lev Execute shift
31	FJ-13R	0.1- to 100-ms DTS H-13	Ping Ctr Output Displ Gating
32	FJ-13S	1000-ms DTS H-13	Reset lev shift

APPENDIX C
Position-Determining System
Interconnecting Cables and Functions

Cable 1				
3C End Pin	3C End		Function	
	Card	Color	Card	
A	D1-8	Pink	B30-14	Mute A
B	D1-9	Violet	A24-14	TT 800
C	D1-10	GN/RD	A24-39	TT 1000
D	D1-11	R/WH/BK	A24-9	TT 2000
E	D1-12	Tan	A24-7	TT 4000
F	D1-13	OR	A24-34	TT 8000
H	D1-14	GN	A24-12	Sig D H10
J	D1-15	WH	A24-33	Sig D H11
K	D1-16	WH/V	A24-43	Sig D H12
L	D1-17	R/Y	B30-43	Sig D H13
M	D1-18	WH/Y	B32-8	In Cy Rst
N	D1-19	WH/GN	B30-39	Sc No "1"
P	D1-20	BK	B30-10	Sc No "2"
R	D1-21	R	B29-34	Pn No 1
S	D1-22	WH/GY	B29-14	Pn No 2
T	D1-23	R/BK	B29-7	Pn No 4
U	D1-24	BU	B29-41	Pn No 8
V	D1-25	Y	B29-31	Pn No 10
W	D1-26	WH/TAN	B29-12	Pn No 20
X	D1-27	BN	B29-9	Pn No 40
Y	D1-28	WH/BK	B29-38	Pn No 80
Z	D1-29	WH/R	B30-7	Pn No 100
a	D1-30	WH/BU	B30-12	Pn No 200
b	D1-31	WH/BN	B30-31	Pn No 400

Cable 2				
3C End Pin	3C End		Function	
	Card	Color	Card	
A	E1-8	Pink	A6-43	TT 0.1
B	E1-9	Violet	A6-9	TT 0.2
C	E1-10	GN/RD	A6-34	TT 0.4
D	E1-11	R/WH/BK	A6-39	TT 0.8
E	E1-12	Tan	A6-7	TT 1
F	E1-13	OR	A12-9	TT 2
H	E1-14	GN	A12-7	TT 4
J	E1-15	WH	A12-33	TT 8
K	E1-16	WH/V	A12-39	TT 10
L	E1-17	R/Y	A12-34	TT 20
M	E1-18	W/Y	A18-9	TT 40
N	E1-19	W/GN	A18-12	TT 80
P	E1-20	BK	A18-39	TT 100
R	E1-21	R	A18-7	TT 200
S	E1-22	W/GY	A18-34	TT 400
T	E1-23	R/BK	A6-14	Sig D H1
U	E1-24	BLU	A6-12	Sig D H2
V	E1-25	Y	A6-33	Sig D H3
W	E1-26	WH/TAN	A12-43	Sig D H4
X	E1-27	BN	A12-14	Sig D H5
Y	E1-28	WH/BK	A12-12	Sig D H6
Z	E1-29	WH/R	A18-33	Sig D H7
a	E1-30	WH/BU	A18-43	Sig D H8
b	E1-31	WH/BN	A18-14	Sig D H9

Position-Determining System
Interconnecting Cable and Functions (Continued)

Cable 3		
3C End Card	Cbl Pin	Control Panel Function
F1-8	A	Gnd Hyd Sig BNC H1
F1-9	B	To Oscillogph H2
F1-10	C	To Oscillogph H3
F1-11	D	To Oscillogph H4
F1-12	E	To Oscillogph H5
F1-13	F	To Oscillogph H6
F1-14	H	To Oscillogph H7
F1-15	J	To Oscillogph H8
F1-16	K	To Oscillogph H9
F1-17	L	To Oscillogph H10
F1-18	M	To Oscillogph H11
F1-19	N	To Oscillogph H12
F1-20	P	To Oscillogph H13
F1-21 to 31	Open	

Cable 4		
3C End Card	Cbl Pin	Control Panel Function
C24-8	A	SPDR Mode Heel For H7
C24-9	B	SPDR Mode Heel For H9
C24-10	C	SPDR Mode Heel For H10
C24-11	D	SPDR Mode Heel For H11
C24-12	E	SPDR Mode Heel For H12
C24-13	F	RST PNG CTR PB
C24-14	H	Ext 10 kHz BNC Jack
C24-15	J	T/P Gate BNC Jack
C24-16	K	Mon Rly to OSC Jack A HL
C24-17	L	Mon Rly to OSC Jack B NO
C24-18	M	Mon Rly to OSC Jack C NC
C24-19	N	Hold Rly to OSC Jack D HL
C24-20	P	Hold Rly to OSC Jack E NO
C24-21	R	Hold Rly to OSC Jack F NC
C24-22	S	Time-Mk to OSC Jack H
C24-23	T	PL Com Return
C24-24	U	REC Gate BNC Jack
C24-25	—	—
C24-26	—	—
C24-27	—	—
C24-28	—	—
C24-29	—	—
C24-30	—	—
C24-31	—	—

Cable 5		
3C End Card	Cbl Pin	Control Panel Function
C25-8	A	PST No (7+8)(S) To SSM Sw
C25-9	B	PST No (7+9)(NE) {
C25-10	C	PST No (7+9)(NW) { See Fig F2
C25-11	D	PST No (1+13)(NW){
C25-12	E	PST No (2+12)(NW)
C25-13	F	—
C25-14	H	Sc Sc to T/I 1 SW
C25-15	J	NE Sc to T/P 2 SW
C25-16	K	NW Sc to T/P 3 SW
C25-17	L	From T/P SW 1 to Sensing
C25-18	M	From T/P SW 2 to Sensing
C25-19	N	From T/P SW 3 to Sensing
C25-20	P	T/P RST to Pre-Run Sw Heel
C25-21	R	Fm Pr-Rn Sw See Fig F1
C25-22	S	Fm Pr-Rn Sw See Fig F1
C25-23	T	Fm Pr-Rn Sw See Fig F1
C25-24	U	Fm Pr-Rn Sw See Fig F1
C25-25	V	Fm Pr-Rn Sw See Fig F1
C25-26	W	Fm Pr-Rn Sw See Fig F1
C25-27	X	SPDR Mode Heel For H2
C25-28	Y	SPDR Mode Heel For H3
C25-29	Z	SPDR Mode Heel For H4
C25-30	a	SPDR Mode Heel For H5
C25-31	b	SPDR Mode Heel For H6

**Position-Determining System
Interconnecting Cables and Functions (Continued)**

Cable 6		
Card	Cbl Pin	Control Panel Function
B25-8	A	Recycle Inhibit
B25-9	B	Sec Dly SW "1"s
B25-10	C	Sec Dly Sw "2"s
B25-11	D	Sec Dly Sw "4"s
B25-12	E	Sec Dly Sw Heel 1
B25-13	F	Sec Dly Sw Heel 2
B25-14	H	Sec Dly Sw Heel 4
B25-15	J	S Selected to Up/X SS Mode
B25-16	K	NE
B25-17	L	NW
B25-18	M	SS Mode Heel Vp/X Mute
B25-19	N	Ext 100 KC Bnc Jack
B25-20	P	Run PL
B25-21	R	In Seq PL
B25-22	S	Gnd
B25-23	T	Pst No 13 To SSM Sw
B25-24	U	Pst No 12 See Fig. F2
B25-25	V	Pst No 11 + 3 See Fig F2
B25-26	W	Pst No 10 + 4 See Fig F2
B25-27	X	Pst No 9 + 6 See Fig. F2
B25-28	Y	Pst No 8 + 5 See Fig F2
B25-29	Z	Pst No 9 + 7 See Fig F2
B25-30	a	Pst No 10 + 11 See Fig F2
B25-31	b	Pst No 10 + 11 See Fig F2

Cable 7		
Card	Cbl Pin	Control Panel Function
A25-8	A	1-kHz Sync BNC Jack
A25-9	B	Pos Icc Xmtr BNC (Rem STT)
A25-10	C	Stt PB Output
A25-11	D	Ready PL
A25-12	E	Stop and Rst PB
A25-13	F	Posdets Mode Sw (A)
A25-14	H	Posdets Mode Sw Man Mo Rst
A25-15	J	Posdets Mode Sw Rst Con FF
A25-16	K	Posdets Mode Sw Gt 8 Sec
A25-17	L	Posdets Mode Sw Adv Seq Ctr
A25-18	M	Posdets Mode Sw (N)
A25-19	N	Posdets Mode Sw Dly Ctr INH
A25-20	P	Posdets Mode Sw Seq Out INH
A25-21	R	Posdets Mode Sw S1/S2/S3 Sel
A25-22	S	Posdets Mode Sw S1 Sel (5)
A25-23	T	Posdets Mode Sw S2 Sel (NW)
A25-24	U	Posdets Mode Sw S3 Sel (NE)
A25-25	V	Posdets Mode Sw Set Seq 1
A25-26	W	Posdets Mode Sw Rst Eq. 1
A25-27	X	Posdets Mode Sw Set Seq 2
A25-28	Y	Posdets Mode Sw Rst Seq 2
A25-29	Z	Posdets Mode Sw (D)
A25-30	a	Posdets Mode Sw (D)
A25-31	b	Posdets Mode Sw F,G

Position-Determining System
Interconnecting Cables and Functions (Continued)

Cable A			Cable B		
SDS End	Cable Pin	Control Panel Function	SDS End	Cable Pin	Control Panel Function
A30-36	A	T/P Switch NO	B26-40	A	Rst Seq PB
A2-5,30	B	Time Display: 0.1 msec	B26-17	B	Man/Auto Display Output Sw
A2-11,39	C	Time Display: 0.2 msec	B26-13	C	T/P Switch NO
A4-5,30	D	Time Display: 0.4 msec	B27-50	D	M/A Displ Out Sw—Man
A4-11,39	E	Time Display: 0.8 msec	B22-26	E	① Displ Out Sw—Auto
A8-5,30	F	Time Display: 1 msec	B27-43	F	Man Adv Sw, NO
A8-11,39	H	Time Display: 2 msec	B27-44	H	Man Adv Sw, NC
A10-5,30	J	Time Display: 4 msec	B28-30	J	Hyd No Displ "1"
A10-11,39	K	Time Display: 8 msec	B28-37	K	Hyd No Displ "2"
A14-5,30	L	Time Display: 10 msec	B28-29	L	Hyd No Displ "4"
A14-11,39	M	Time Display: 20 msec	B28-3	M	Hyd No Displ "8"
A16-5,30	N	Time Display: 40 msec	B28-50	N	Hyd No Displ "10"
A16-11,39	P	Time Display: 80 msec	—	P	—
A20-5,30	R	Time Display: 100 msec	B21-21	R	Mode Sw: Mode 1
A20-11,39	S	Time Display: 200 msec	B17-6	S	Mode Sw: Mode 2
A22-5,30	T	Time Display: 400 msec	B17-11	T	Mode Sw: Mode 3
A22-11,39	U	Time Display: 800 msec	B17-1	U	Mode Sw: Mode 4
A26-5,30	V	Time Display: 1000 msec	B17-5	V	Mode Sw: Mode 5
A26-11,39	W	Time Display: 2000 msec	B21-23	W	Mode No Displ "1"
A28-5,30	X	Time Display: 4000 msec	B17-4	X	Mode No Displ "2"
A28-11,39	Y	Time Display: 8000 msec	B17-3	Y	Mode No Displ "4"
—	Z	+5 V	B30-1	Z	Se No Displ "1"
—	a	Ground	B31-13	a	Se No Displ "2"
—	b	—	—	b	—

Cable C			Cable C		
SDS End	Cable Pin	Control Panel Function	SDS End	Cable Pin	Control Panel Function
B29-25	A	Ping No Displ 1	B19-29	P	Tape Perf Out 2
B29-22	B	Ping No Displ 2	B19-27	R	Tape Perf Out 4
B29-3	C	Ping No Displ 4	B19-33	S	Tape Perf Out 8
B29-46	D	Ping No Displ 8	B19-30	T	Tape Perf Out 16
B29-26	E	Ping No Displ 10	B19-15	U	Tape Perf Out 32
B29-23	F	Ping No Displ 20	B26-47	V	Select Hyd No PB
B29-1	H	Ping No Displ 40	B26-37	W	Select Hyd No Sw 1
B29-47	J	Ping No Displ 80	B26-43	X	Select Hyd No Sw 2
B30-3	K	Ping No Displ 100	B26-39	Y	Select Hyd No Sw 4
B30-23	L	Ping No Displ 200	B26-41	Z	Select Hyd No Sw 8
B30-26	M	Ping No Displ 400	B19-19	a	Tape Perf Clk Out
B19-21	N	Tape Perf Out 1	—	b	—

APPENDIX D
Sample Computer Instructions and Readout

SEA SPIDER I SAMPLE OPERATING INSTRUCTIONS

LOAD SUBPROGRAM

ENTER DEPTHBOT

18869.*

LOAD VELOCITY DATA TAPE

PUNCH LEADER

ENDING PART I, PUNCH TRAILER LOAD SPIDER II

SEA SPIDER II SAMPLE OPERATING INSTRUCTIONS

LOAD SUBPROGRAM

LOAD TAPE FROM PART I AT THIS TIME
ENTER UTAH

15826.6*

ENTER HOTEL

27412.5*

ENTER DOG

-15826.6*

LOAD DATA TAPE

PING(J) = 1

PING(J) = 3

PING(J) = 3

ENTER CORRECTIONS FOR ABOVE PINGS IN SEQUENCE

3233454631020*

ENTER CORRECTIONS FOR ABOVE PINGS IN SEQUENCE

0433434520420

ENTER CORRECTIONS FOR ABOVE PINGS IN SEQUENCE

2243343442320*

READY FOR PRINTOUT, TURN TO CLEAN PAGE AND PRESS START

*TYPE IN RESPONSE TO INSTRUCTION

Sample Computer Instructions and Readout (Continued)

SAMPLE VELOCITY PROFILE DATA TAPE.

16 UNIQUE	18400.	16000.	13000.	10500.	10072.
HYDROPHONE					
DEPTHS	10015.	10000.	6000.	3000.	2623.
	2572.	2538.	2515.	2500.	300.
	150.	000.			
NO. OF	9				
INFLECTION POINTS					
VELOCITY			DEPTH OF INFLECTION		
AT INFLECTION	5100.0	18400.	1		
	4945.8	9843.	2		
	4880.7	5680.	3		
	4864.8	3281.	4		
	4845.7	2360.	5		
	4883.4	1320.	6		
	4906.5	993.	7		
	5026.5	280.	8		
	5021.3	000.	9		
VELOCITY OF	5105.9				
SOUND AT BOTTOM					

Sample Computer Instructions and Readout (Continued)

SAMPLE DATA TAPE. CONTAINS PING NO., SOURCE NO., 36 TRAVEL
TIMES, AND MODE.

PING NO.	001				
SOURCE NO.	01				
13 TRAVEL	6199.2	5849.6	5475.6	5240.2	5203.7
TIMES	5033.8	5065.1	5085.9	5204.8	5212.7
	4525.7	5080.4	0000.0		
MODE	05				
PING NO.	002				
SOURCE NO.	02				
13 TRAVEL	0000.0	0672.3	1514.8	2224.7	2368.4
TIMES	3517.5	4388.7	4535.0	5166.2	5206.4
	5083.3	5080.4	0000.0		
MODE NO.	05				
PING NO.	003				
SOURCE NO.	03				
13 TRAVEL	6198.2	5849.6	5476.6	5240.2	5202.7
TIMES	5032.8	5064.1	5083.9	5205.8	5213.7
	5082.3	4521.0	0000.0		
MODE NO.	05				

Sample Computer Instructions and Readout (Continued)

SAMPEL VALUES OF THE HYMO ARRAY. THESE VALUES WERE
OBTAINED BY USING THE TEST DATA. NUMBERS SHOWN ARE AVERAGE
VELOCITY, THE FIVE MODES ARE THE COLUMNS, THE HYDROPHONES
THE TWELVE ROWS.

	MODE				
	1	2	3	4	5
1	5108.45	5108.45	5108.45	5108.45	5108.45
2	5028.82	5028.82	5028.82	5028.82	5078.38
3	5024.96	5024.96	5024.31	5024.31	5051.35
4	5024.45	5024.45	4966.99	4966.99	5028.82
5	5024.31	5024.31	4964.56	4964.56	5024.31
6	4966.99	4966.99	4964.24	4964.24	4989.69
7	4964.24	4964.24	4964.02	4964.02	4966.99
8	4963.88	4963.88	4963.88	4963.88	4963.79
9	4963.79	4963.79	4963.79	4963.79	4956.70
10	4956.70	4956.70	4957.26	4957.26	4957.26
11	4963.88	5078.38	5078.38	4964.24	4964.88
12	4963.79	5051.35	5051.35	4963.79	4964.02

Sample Computer Instructions and Readout (Continued)

SAMPLE ANSWER PAGE. DATA AND ANSWERS ARE THOSE OBTAINED
WHEN TESTING THE PROGRAM.

NS= 1 PING(NS)= 1

MODE= 5

TRAVEL TIMES

6199.200005849.600015475.600015240.200005203.70000
5033.800005065.100015085.900015204.800005212.70000
4525.700005080.40001 0.00000

x x x x x x x

CORRECTIONS

3 2 3 3 4 5 4 6 3 1 0 2 0

NS= 2 PING(NS)= 2

MODE= 5

TRAVEL TIMES

0.00000 672.300001514.800002224.700002368.40000
3517.500004388.700004535.000005166.200005206.40001
5083.300005080.40001 0.00000

x x x x x x x

CORRECTIONS

0 4 3 3 4 3 4 5 2 0 4 2 0

NS= 3 PING(NS)= 3

MODE= 5

TRAVEL TIMES

6198.200005849.600015476.600015240.200005202.70000
5032.800005064.100015083.900015205.800005213.70000
5082.300005421.00000 0.00000

x x x x x x x

CORRECTIONS

2 2 4 3 3 4 3 4 4 2 3 2 0

Sample Computer Instructions and Readout (Continued)

SAMPLE ANSWER PAGE CONTINUED

X	Y	Z
27412.35	15826.38	0.00
26212.56	13746.26	2399.82
24712.51	11150.11	5399.88
23462.49	8985.01	7900.35
23212.42	8551.88	8399.98
21212.48	5087.88	12400.01
19712.53	2489.90	15399.91
19462.46	2056.75	15899.90
18362.32	151.26	18099.85
18287.37	21.43	18249.87
15885.21	0.00	15885.14
19481.51	-2089.76	15862.26

END OF PRINTOUT, SET NEW PAGE, TYPE -2. TO ENTER NEXT
DATA BLOCK, TYPE 0. TO ENTER NEW U.H.D. TYPE 2.
TO END PROGRAM AND ENTER NEW VELOCITIES

APPENDIX E **Position-Determining System**

Wiring Chart—SDS Library A—From Data Storage Output to Output or Gates

0.1 Millisecond Decade							
0.1 MS Bit		0.2 MS Bit		0.4 MS Bit		0.8 MS Bit	
From	To	From	To	From	To	From	To
1-5	2-3	1-9	2-10	1-3	4-2	1-4	4-10
1-17	2-7	1-21	2-17	1-13	4-7	1-18	4-17
1-31	2-29	1-35	2-40	1-25	4-29	1-28	4-40
1-43	2-36	1-47	2-45	1-39	4-36	1-40	4-43
3-5	2-4	3-9	2-12	3-3	4-3	3-4	4-12
3-17	2-8	3-21	2-18	3-13	4-8	3-18	4-18
3-31	2-31	3-35	2-41	3-25	4-31	3-28	4-41
3-43	2-37	3-47	2-46	3-39	4-37	3-40	4-44
5-5	2-6	5-9	2-13	5-3	4-4	5-4	4-13
5-17	2-9	5-21	2-19	5-13	4-9	5-18	4-19
5-31	2-33	5-35	2-42	5-25	4-33	5-28	4-42
5-43	2-38	5-47	2-47	5-39	4-38	5-40	4-45

No Change in Pin Numbers, Only in Card Numbers

1 Millisecond Decade			
Change 1, 3, 5 To 7, 9, 11 And 2 to 8	Change 1, 3, 5 To 7, 9, 11 And 2 to 8	Change 1, 3, 5 To 7, 9, 11 And 4 to 10	Change 1, 3, 5 To 7, 9, 11 And 4 to 10
10 Millisecond Decade			
Change 1, 3, 5 To 13, 15, 17 And 2 to 14	Change 1, 3, 5 To 13, 15, 17 And 2 to 14	Change 1, 3, 5 To 13, 15, 17 And 4 to 16	Change 1, 3, 5 To 13, 15, 17 And 4 to 16
100 Millisecond Decade			
Change 1, 3, 5 To 19, 21, 23 And 2 to 20	Change 1, 3, 5 To 19, 21, 23 And 2 to 20	Change 1, 3, 5 To 19, 21, 23 And 4 to 22	Change 1, 3, 5 To 19, 21, 23 And 4 to 22
1000 Millisecond Decade			
Change 1, 3, 5 To 25, 27, 29 And 2 to 26	Change 1, 3, 5 To 25, 27, 29 And 2 to 26	Change 1, 3, 5 To 25, 27, 29 And 4 to 28	Change 1, 3, 5 To 25, 27, 29 And 4 to 28

APPENDIX F
Complete System Schematics

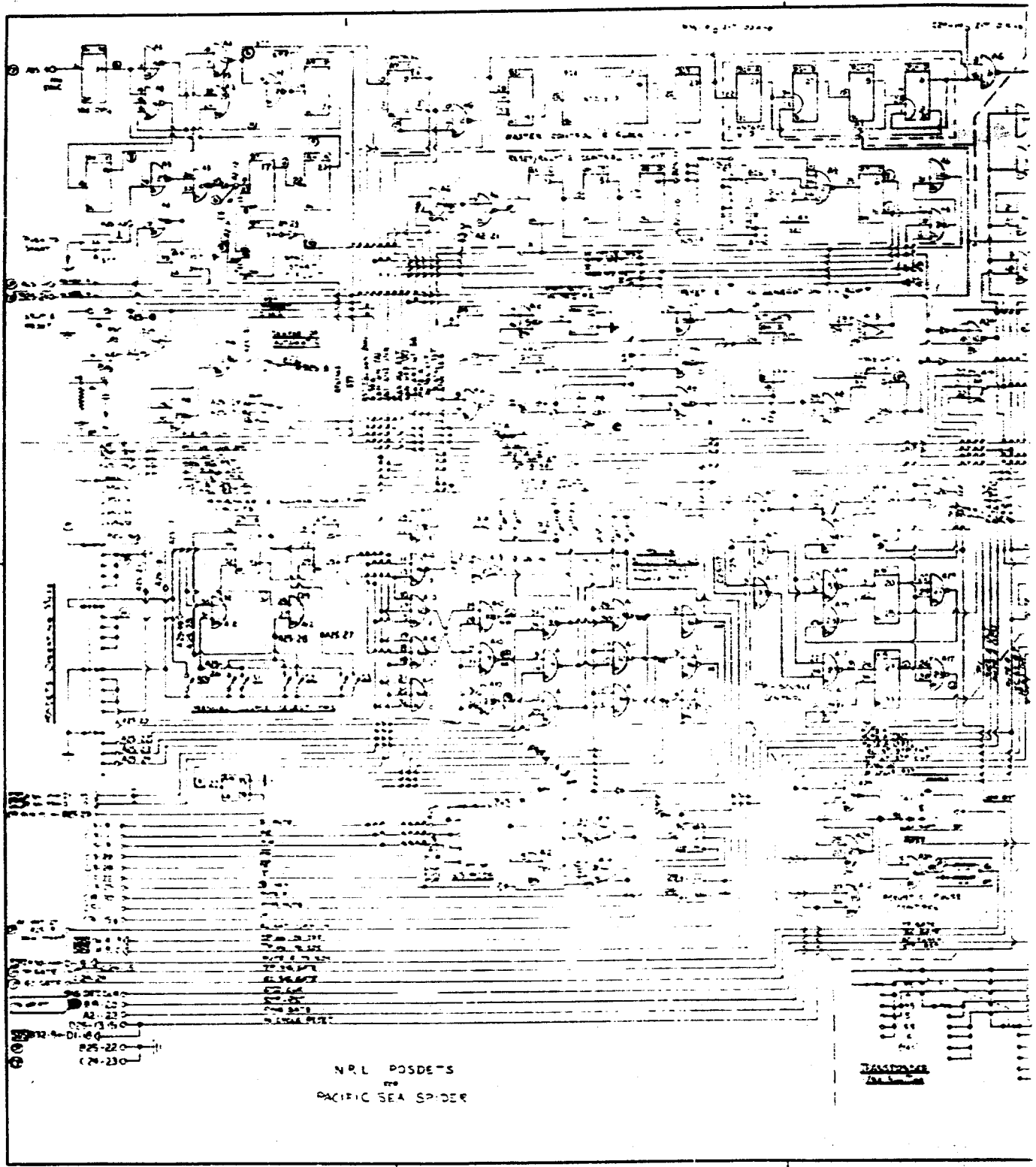
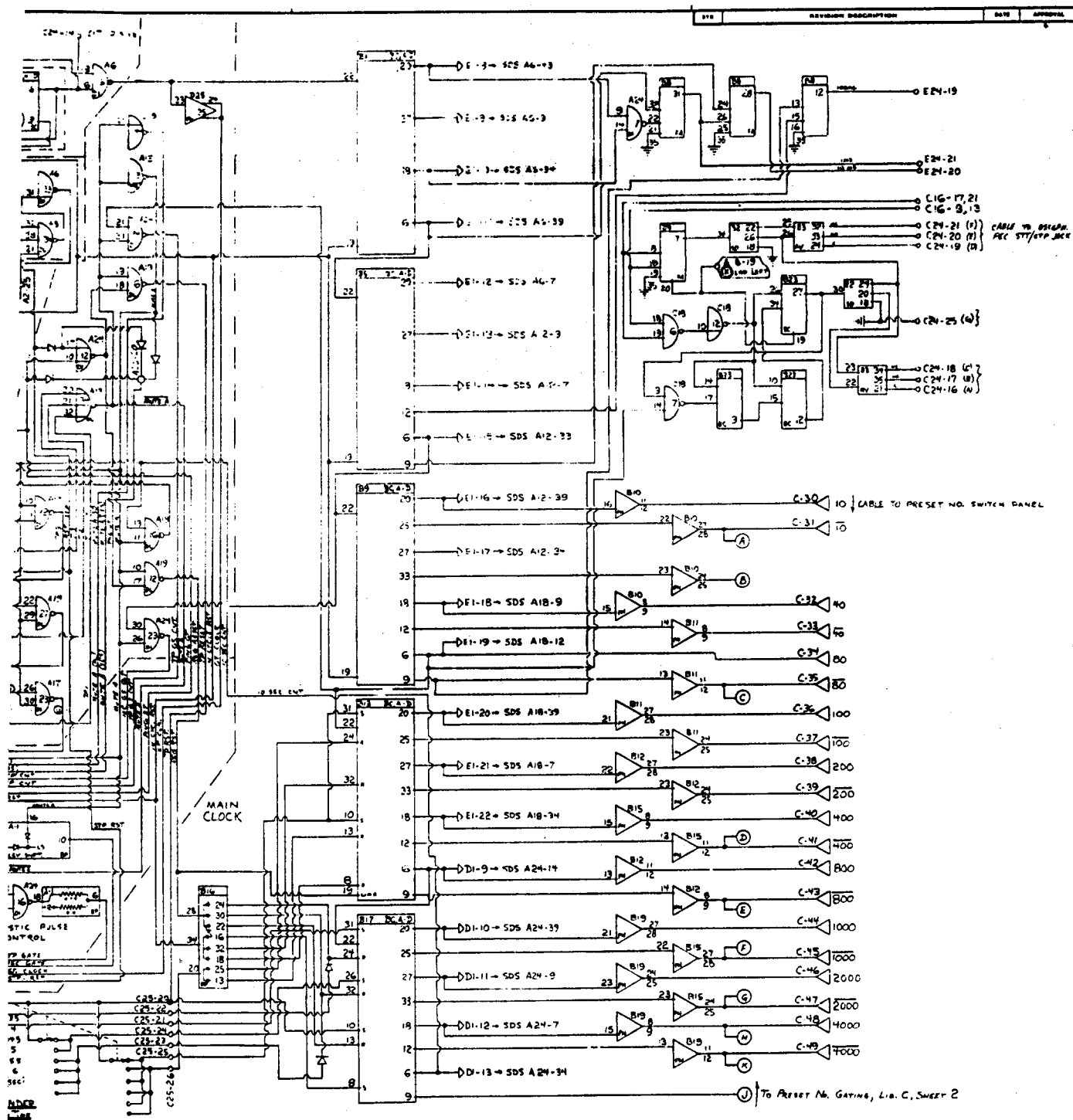


Fig. F1—Control and c

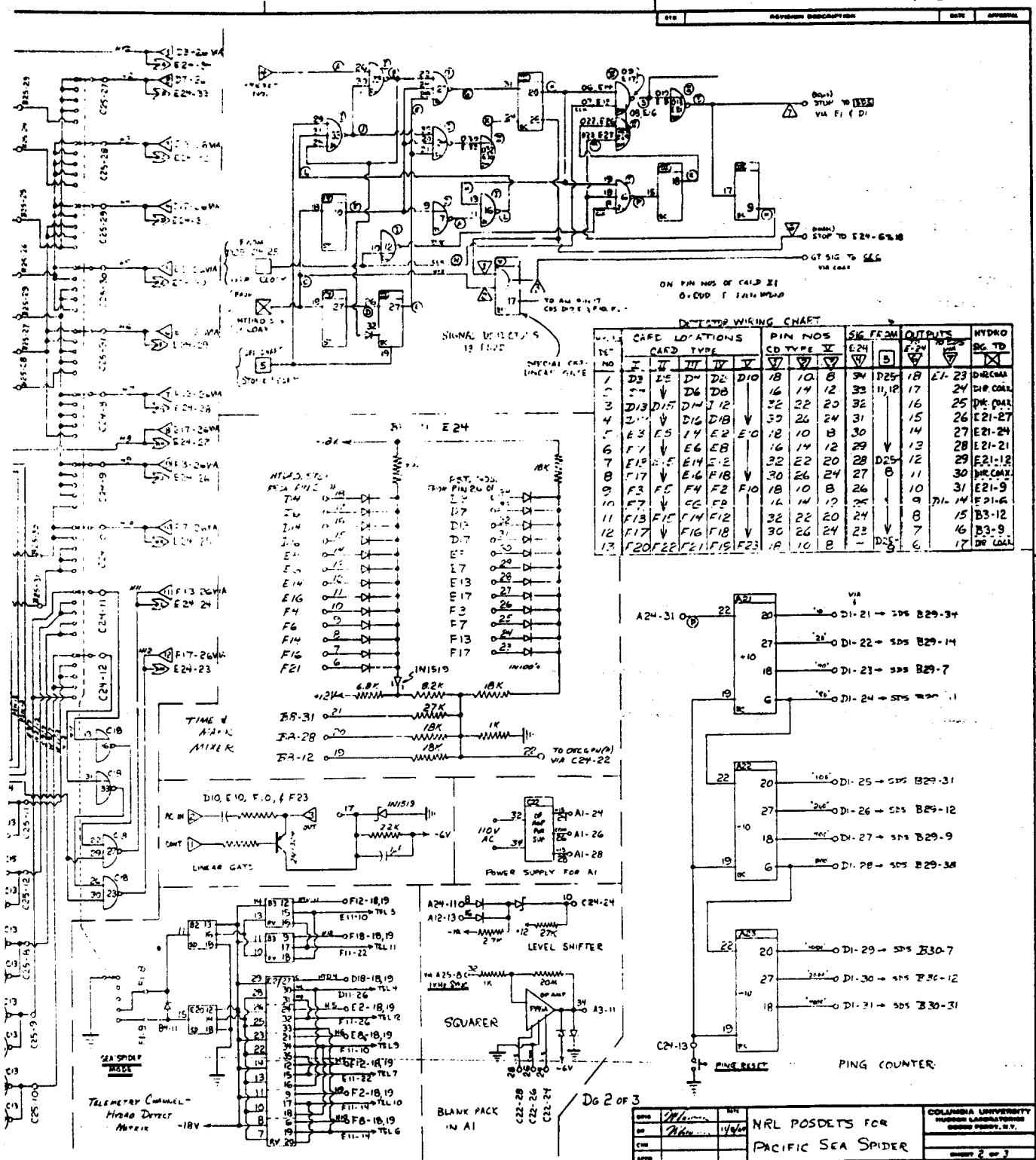
Preceding page blank

2-



DG 1 of 3

DATE	11/1/61	BY	W. J. M.	NRL POSSETS FOR PACIFIC SEA SPIDER	COLUMBIA UNIVERSITY NUCLEAR LABORATORIES GREENSBORO, N.C. SHEET 1 OF 3
NO.	11/1/61	BY	W. J. M.		
REV.		BY			
APP.		BY			



3, signal detector, and miscellaneous circuits

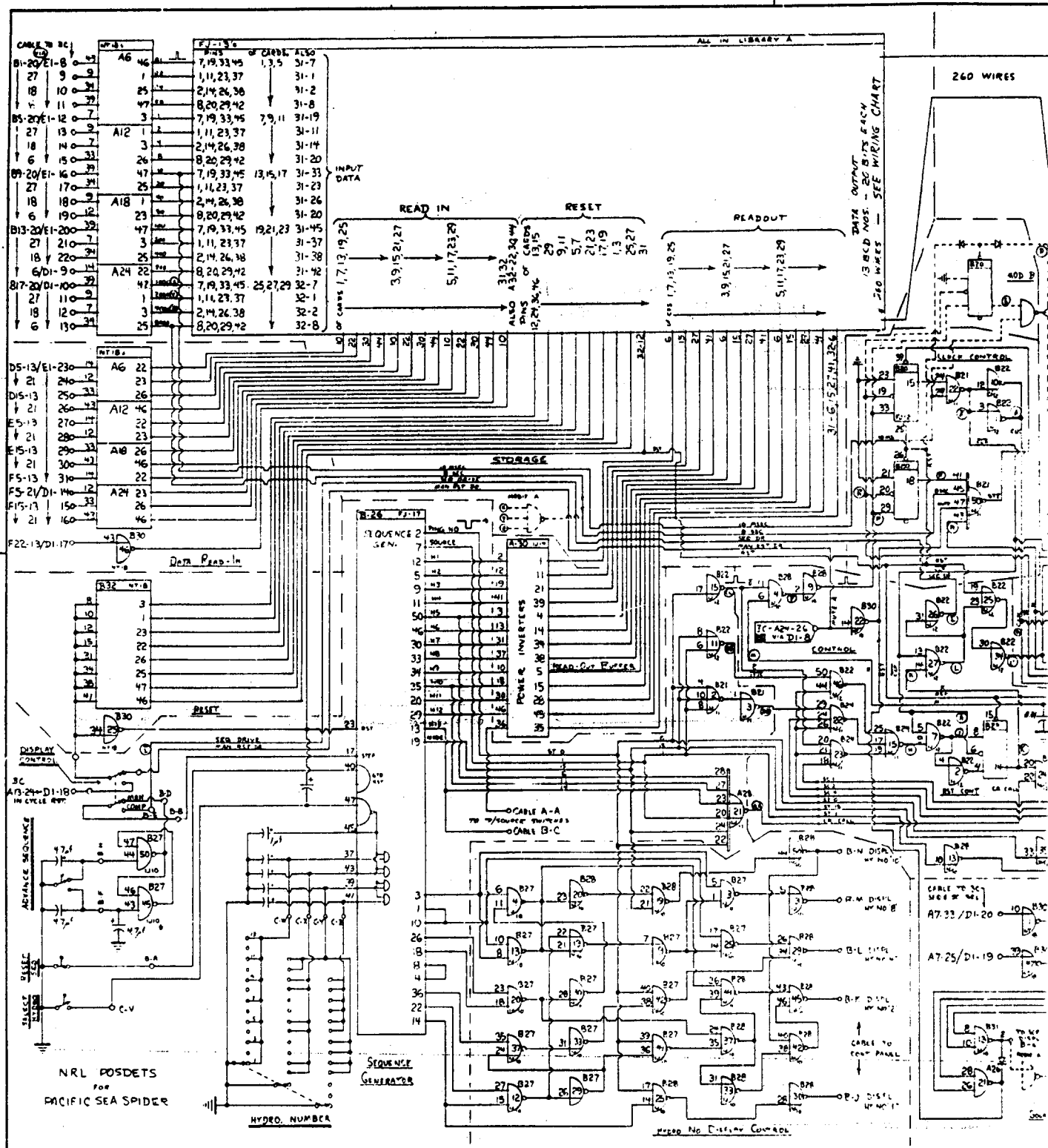


Fig. F3—Data storage and reado



Security Classification		
DOCUMENT CONTROL DATA - R & D		
Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified:		
1. ORIGINATING ACTIVITY (Corporate author)		2a. REPORT SECURITY CLASSIFICATION
Naval Research Laboratory Washington, D.C. 20390		Unclassified
		2b. GROUP
3. REPORT TITLE		
POSITION-DETERMINING SYSTEM FOR SEA-SPIDER HYDROPHONE ARRAYS		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates)		
Final report on the NRL Problem.		
5. AUTHOR(S) (First name, middle initial, last name)		
W.M. Lawson, Jr.		
6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF FIGS.
December 30, 1971	64	0
8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)	
NRL Problem K03-42	NRL Report 7322	
b. PROJECT NO.		
R2408		
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)	
d.		
10. DISTRIBUTION STATEMENT		
Distribution limited to U.S. Government Agencies only; test and evaluation; December 1971. Other requests for this document must be referred to the Director, Naval Research Laboratory, Washington, D.C. 20390.		
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY
		Department of the Navy Office of Naval Research Arlington, Virginia 22217
13. ABSTRACT		
<p>An electronic system has been developed which is capable of measuring the elapsed travel time for three acoustic sources to any one of 12, 24, or 36 hydrophones. Though it was developed and configured for the Pacific Sea-Spider array, it is applicable, with modifications, for determining the position of 12 hydrophones relative to three sources in known positions.</p> <p>Pacific Sea-Spider was a trilegged, moored, subsurface array of 30 hydrophones. It had three acoustic sources, one near each anchor point. The position-determining system developed for this array includes control logic to select any of five sets of 12 hydrophones and a single source, a crystal-controlled clock to measure the travel time, 12 level and phase detectors to determine reception of the acoustic signal and to command time transfer, a storage register with jam transfer of the time data, and output logic to control a paper-tape punch for data output.</p> <p>The acoustic signal is gated synchronously, and axis-crossing detection is used. The result is a resolution of a 0.1 ms, provided a graphic recorder is used to note the number of the cycle at which detection occurred.</p> <p>The results on paper tape can be either printed out on a typewriter or used as data input to a digital computer, where with proper programming the coordinates of a particular hydrophone with respect to the known position of the three sources can be calculated.</p> <p>The system can complete a set of elapsed-time measurements for 12 hydrophones once every 10 seconds. In the Sea-Spider configuration with three legs and 30 hydrophones, the minimum time for a complete set of elapsed-time measurements is 30 seconds.</p>		

DD FORM 1473 (PAGE 1)

1 NOV 65

S/N 0101-807-6801

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Position-determining system (POSDETS) Pacific Sea-Spider Hydrophone array Undersea acoustic travel time Level detection Axis-crossing Schmidt triggers Preset-number muting system						

UNITED STATES GOVERNMENT

Memorandum

7103/422:BGH:tec

DATE: 24 October 2001

FROM: Burton G. Hurdle (NRL Code 7103)


SUBJECT: REVIEW OF REF. (a) FOR REMOVAL OF RESTRICTIONS

TO: 1221.1 *fs 10/26/01*

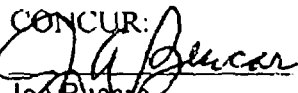
VIA: Code 7100

REF: (a) "Position-Determining System for Sea-Spider Hydrophone Arrays", W.M. Lawson, Jr.,
NRL Report 7322, December 30, 1971. (Unclassified)

1. Reference (a) is an acoustic method for determining the distances and locations of an array of hydrophones on the ocean floor. It is currently restricted.
2. The science and technology of this report have long been superseded. The current value of this report is historical.
3. Based on the above, it is recommended that reference (a) be available with no restrictions.


BURTON G. HURDLE
NRL Code 7103

CONCUR:


Joe Bucare
Acting Superintendent
Acoustics Division*10/25/01*
DateCopy to:
Code 5227 (Mary Templeman)

Page: 1 Document Name: untitled

-- 1 OF 1
-- 1 - AD NUMBER: 891210
-- 2 - FIELDS AND GROUPS: 13/10
-- 3 - ENTRY CLASSIFICATION: UNCLASSIFIED
-- 5 - CORPORATE AUTHOR: NAVAL RESEARCH LAB WASHINGTON D C
-- 6 - UNCLASSIFIED TITLE: POSITION-DETERMINING SYSTEM FOR SEA-SPIDER
-- HYDROPHONE ARRAYS.
-- 8 - TITLE CLASSIFICATION: UNCLASSIFIED
-- 9 - DESCRIPTIVE NOTE: FINAL REPT.,
-- 10 - PERSONAL AUTHORS: LAWSON,W. M. , JR;
-- 11 - REPORT DATE: 30 DEC 1971
-- 12 - PAGINATION: 62P MEDIA COST: \$ 7.00 PRICE CODE: AA
-- 14 - REPORT NUMBER: NRL-7322
-- 16 - PROJECT NUMBER: NRL-K03-42, NRL-R24-08
-- 20 - REPORT CLASSIFICATION: UNCLASSIFIED
-- 22 - LIMITATIONS (ALPHA): DISTRIBUTION LIMITED TO U.S. GOV'T.
-- AGENCIES ONLY; TEST AND EVALUATION; DEC 71. OTHER REQUESTS FOR
-- THIS DOCUMENT MUST BE REFERRED TO DIRECTOR, NAVAL RESEARCH LAB.,
-- WASHINGTON, D. C. 20390.
-- 23 - DESCRIPTORS: (*STABILIZED PLATFORMS, *HYDROPHONES), NETWORKS,
-- ACOUSTIC SIGNALS, SOURCES, DIGITAL COMPUTERS, CONFIGURATION, DESIGN,
-- CLOCKS
-- 24 - DESCRIPTOR CLASSIFICATION: UNCLASSIFIED
--
-- 25 - IDENTIFIERS: *SEA SPIDER PROJECT, TRAVEL TIME
-- 26 - IDENTIFIER CLASSIFICATION: UNCLASSIFIED
-- 27 - ABSTRACT: AN ELECTRONIC SYSTEM HAS BEEN DEVELOPED WHICH IS
-- CAPABLE OF MEASURING THE ELAPSED TRAVEL TIME FOR THREE ACOUSTIC
-- SOURCES TO ANY ONE OF 12, 24, 36 HYDROPHONES. THOUGH IT WAS
-- DEVELOPED AND CONFIGURED FOR THE PACIFIC SEA-SPIDER ARRAY, IT IS
-- APPLICABLE, WITH MODIFICATIONS, FOR DETERMINING TE POSITION OF 12
-- HYDROPHONES RELATIVE TO THREE SOURCES IN KNOWN POSITIONS. PACIFIC
-- SEA-SPIDER WAS A TRILEGGED, MOORED, SUBSURFACE ARRAY OF 30
-- HYDROPHONES. IT HAD THREE ACOUSTIC SOURCES, ONE NEAR EACH ANCHOR
-- POINT. THE POSITION-DETERMINING SYSTEM DEVELOPED FOR THIS ARRAY
-- INCLUDES CONTROL LOGIC TO SELECT ANY OF FIVE SETS OF 12 HYDROPHONES
-- AND A SINGLE SOURCE, A CRYSTAL-CONTROLLED CLOCK TO MEASURE THE
-- TRAVEL TIME, 12 LEVEL AND PHASE DETECTORS TO DETERMINE RECEPTION OF
-- THE ACOUSTIC SIGNAL AND TO COMMAND TIME TRANSFER, A STORAGE
-- REGISTER WITH JAM TRANSFER OF THE TIME DATA, AND OUTPUT LOGIC TO
-- CONTROL A PAPER-TAPE PUNCH FOR DATA OUTPUT. (AUTHOR)
-- 28 - ABSTRACT CLASSIFICATION: UNCLASSIFIED
-- 29 - INITIAL INVENTORY: 1
-- 33 - LIMITATION CODES: 3
-- 34 - SOURCE SERIES: F
-- 35 - SOURCE CODE: 251950

Date: 10/26/01 Time: 1:08:10PM

**APPROVED FOR PUBLIC
RELEASE - DISTRIBUTION
UNLIMITED**